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PROPORTIONS OF PINS USED IN BRIDGES.

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It is not the least of the merits of skeleton structures, such as are built by the best American constructors, that any of the parts can be exactly calculated. The determination of strains acting in pins is not excepted from this statement, though it is connected with the application of some of the finer laws of the theory of elasticity.*

All rules referring to the size of pins can be immediately deduced from the few physical principles on which the theory of elasticity is based, and without new experiments. On the contrary, sound practice would have further advanced and mistakes been avoided, if, at least, a scientific examination of the subject had been undertaken previous to experiment, in order to arrive at a distinct opinion about what confirmation by test was required of the theory of elasticity. There are three questions to be examined in the present paper, viz.:

1. What is the law of distribution of the pressure caused by the tie bar on the bearing surface of the pin.

2. What is the law of distribution of the shearing strain over the cross-section of the pin, and

3. What is the value of its bending moment in any of its sections.

The solution of the first actually includes also that of the third, but it is more convenient to treat the two separately.

For this purpose, consider a top chord pin of a truss bridge, represented by Fig. 1.

The originally straight pin M M is resting on bored bearing surfaces N N, of a top chord casting, and carries two flat eye bars of the width "b" and the thickness "t" placed outside of the casting. This is the arrangement of any pinned bottom chord, or the chains of a suspension bridge, where the outermost bars produce strains analogous to those borne by the parts here shown.

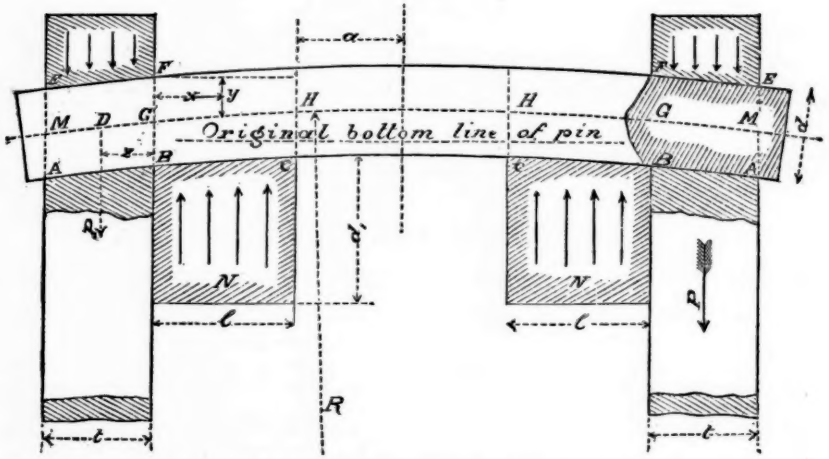
Under strain, the pin M M will be pressed in to the bearings N N, which are supposed to be of a length B C$=l$, and of the depth d. Both bearing surfaces E F, between pin and bars, will be compressed, and a greater share of the total pressure absorbed by the parts of the pin closest to the face of the casting. The pressure per square unit at F will be greater than at E, and likewise the pressure at B than at C. The pin is supposed to accurately fit into its bearings, and (for the present) friction between the cylindrical bearing surfaces is disregarded.

So far as the half cylindrical bearing surface or half circle of any cross section of the pin is concerned, the pressure will not be any more uniformly distributed than is the case for the different points of lines E F

* The article is arranged so that those not quite familiar with higher analysis can omit the mathematical deductions, printed in smaller type.

and B C. The pressure of a pin with play first will be concentrated at a point, but under the load a set will take place, and the pressure be more uniformly distributed over the diameter $r\,r$. The law of this distribution is very complex, and will not be followed up here. It is sufficient for the present to consider the pressure as being uniformly distributed over the diameter of the pin, which, however, is somewhat less than is actually the case. The diameters of pins found under this supposition will be a little *too small;* reasons will be given for assuming this basis of the calculation.

FIG. 1.



It may be added that the strain per square inch will not only decrease in a single ratio with the increase of the pin, but that a larger pin will cause a more uniform distribution of the pressure; the importance of the *least practicable play* in the pin hole is evident.

The pressure per square inch is in direct proportion to the amount of depression; consequently the problem is the same as to find the curve of depression. The curve itself consists of three parts; the central part H H is circular, because the moment of flexure of H and H is of a constant value; the part G H, which differs from H H as well as from M G, will be examined first. Take the origin of the co-ordinates in the surface B F, in the original centre line of the pin, which at G has received a depression $Y\,o$—and for any subsequent abscisses, has a deflection y.

The deflections y, are decreasing towards H, and consequently the first differential will have a negative value.

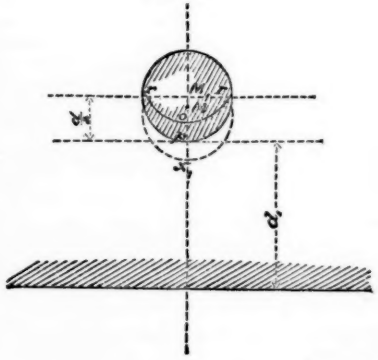
The cross section (Fig. 2) of the pin, represents how the deflection y is composed of two parts: one due to the compression of the pin itself, the other to the compression of the bearing, and fitting to each other. These partial depressions are $\frac{d}{2} \cdot \frac{A\,x}{E}$ and $d \cdot \frac{A\,x}{E}$, where A_x is the pressure per square inch, and E and E are the moduli of tensile elasticity of the material of which respectively the pin and bearing are composed.

The total depression consequently will be:

$$M\,M_1 = O\,p + p\,X = O\,X = \left(\frac{d}{2\,E} + \frac{d_1}{E_1}\right) A\,x$$

$$= \frac{A\,x}{E}\left(\frac{d}{2} + d_1 \cdot \frac{E}{E_1}\right)$$

FIG. 2.



When the bearing is o cast-iron $\frac{E}{E_1}$ can be assumed to be about $= \frac{3}{2}$, so that

$$y = \frac{A\,x}{E}\left(\frac{d}{2} + d_1 \cdot \frac{3}{2}\right)$$

and if

$$\left(\frac{d}{2} + d_1 \cdot \frac{3}{2}\right) = \frac{d}{2} + d_1 \cdot \frac{E}{E_1}$$

is represented by L

There will be the equation

$$y = \frac{A\,x}{E}\,L \quad . \quad . \quad \text{Equation I.}$$

This equation also holds good for the pin-end M G, where L has only to be replaced by a proper part of the length of the bar.

The pressure A_x multiplied by the width of the bearing, represents the increment of the shearing force, taken per unit of the abscissa; it therefore depends simply on the value y, and varies with the abscissa; the law of the curve will be represented by an unknown function of y and X.

The fundamental law of any flexure of a beam is expressed by the equation

$$E\,I \cdot \frac{d^2\,y}{d\,x^2} = M_x \quad . \quad . \quad . \quad \text{II.}$$

which expressed in words is—the product of the modulus of elasticity E, the moment of inertia I, of the section of the beam (here a pin), and the second differential coefficient of y is equal to the moment of exterior forces M_x taken at the point of abscisses considered.

It is known from the elementary theory of elasticity that the first differential coefficient of M_x is the shearing force for the point whose abscissa is x, and that its differential coefficient—the second differential coefficient of M_x is the increment of the shearing strain.

This increment can be derived from equation I., which gives $A_x \cdot d = y \cdot \frac{E\,d}{L}$, whence by taking the second differential of equation II., there is found

$$E\,I\,\frac{d^4\,y}{d\,x^4} = \frac{d^2\,M_x}{d\,x^2} = y \cdot \frac{E\,d}{L}$$

or

$$\frac{d^4\,y}{d\,x^4} = y\left(\frac{d}{I\,L}\right) \quad . \quad . \quad \text{III.}$$

which integrated will give the equation of the curve. This is a lineal differential equation of the fourth order, and when

$$\frac{d}{I\,L} \text{ is called } p^4, \text{ where } p = \sqrt[4]{\frac{a}{I\,L}}$$

it will lead to the general formula: there being $e = 2.7182818$.

$$y = A_1\,e^{px} + A_{11}\,e^{-px} + B_1 \cos p\,x + B_{11} \sin p\,x. \quad \text{IV.}$$

for which the 4 constants must be determined to suit the conditions of the piece G H of the pin.

These are:

(a.) For $x = 0$ or at point a the moment of flexure is a known quantity $= P\,z$ so that

$$E\,I\,\frac{d^2\,y}{d\,x^2} = p^2\,E\,I\,[A_1\,e^{px} + A_{11}\,e^{-px} - B_1 \cos p\,x - B_{11} \sin p\,x]_{x=0} = P \cdot z$$

or by inserting $x = 0$ in the formula

$$A_1 + A_{11} - B_1 = \left(\frac{P\,z}{p^2 \cdot E\,I}\right) = C$$

(b.) For $x = 0$ the shearing force is equal to P, so that

$$\left[E\,I\,\frac{d^3\,y}{d\,x^3}\right] \text{for } x = 0 = p^3\,E\,I\left[A_1 - A_{11} - B_{11}\right] = P$$

$$\text{and } A_1 - A_{11} - B_{11} = \left(\frac{P}{p^3\,E\,I}\right) = C_1.$$

(c.) At the end of the bearing the whole pressure P has been absorbed by the bearing casting, so that

$$\left[E\,I\,\frac{d^3\,y}{d\,x^3}\right] \text{for } x = l = p^3\,E\,I\left[A_1\,e^{pl} - A_1\,e^{-pl} + B_1 \sin p\,l - B_{11} \cos p\,l\right] = 0, \text{ and}$$

$$A_1\,e^{pl} - A_{11}\,e^{-pl} + B_1 \sin p\,l - B_{11} \cos p\,l = 0.$$

(d.) The angle under which the tangent of the curve at H will cut the line of abscisses can be calculated thus:

The piece H H is part of a circle, whose highest point is midway between H and H_1, and if R represents the radius, then will

$$E\,I\,\frac{1}{R} = p^2\,E\,I(A_1\,e^{pl} + A_{11}\,e^{-pl} - B_1 \cos p\,l - B_{11} \sin p\,l)$$

and the tangent of the angle in question, since R is many times greater than $\frac{H\,H}{2} = a$, will be found $= \frac{a}{R}$, this being the absolute value of the tangent, whilst the first differential coefficient $\frac{d\,y}{d\,x}$ is negative (as has been already stated); then will

$$a\,p^2\,(A_1\,e^{pl} + A_{11}\,e^{-pl} - B_1 \cos p\,l - B_{11} \sin p\,l) = p\,(A_1\,e^{pl} - A_{11}\,e^{-pl} - B_1 \sin p\,l + B_{11} \cos p\,l)$$

and

$$A_1\,e^{pl}(a\,p - 1) + A_{11}\,e^{-pl}(a\,p + 1) - B_1\,(ap \cos p\,l + \sin p\,l) - B_{11}\,(a\,p \sin p\,l - \cos p\,l) = 0.$$

The four equations a, b, c, and d are sufficient to calculate A_1, A_{11} B_1 and B_{11}, so that equation IV. is fully developed, and, according to equation I. the pressure in any point of the bearing B C, can be found.

This somewhat intricate investigation was necessary to get an idea how the pressure P will be distributed. The subsequent example will illustrate the theory of this—

Let $P = 3'' \times 1'' \times 10000$ lbs. $= 30000$ lbs.

The lever z is very nearly $\frac{1}{4}$ of the thickness of the bar $= \frac{1}{4}''$. The diameter of pin $= 3''$, so that $l = 4$. L can be assumed to be $= 4''$, $l = 1''$, $E = 30000000$ lbs. and $a = 5''$.

The value $p = \sqrt{\frac{5''}{4 \times 4}} = 0.658$ and $p\,l = 0.658$.

$$C = \frac{z \cdot P}{p^2\,E\,I} = \frac{30000}{2 \times 0.658^2 \times 30000000 \times \frac{1}{4}} = 0.0002887$$

$$C_1 = \frac{P}{p^3\,E\,I} = \frac{30000}{0.658^3 \times 30000000 \times 1} = 0.000877.$$

$e^{pl} = 2.71828^{0.658} = 1.931.$
$e^{-pl} = 2.71828^{-0.658} = 0.5179.$
$\sin 0.658 = 0.6115.$
$\cos 0.658 = 0.7912.$

And these values put in the equations *a*, *b*, *c*, *d*, lead to

$$B_1 = -0.000902$$
$$B_{1\,1} = -0.000165$$
$$A_1 = -0.0000493$$
$$A_{1\,1} = -0.0006627.$$

For $x = 0$ there are

$$y\,o = A_1 + A_{1\,1} + B_1 = C + 2B_1 = -0.001615'' \text{ and}$$

$$A\,o = y\,o \frac{E}{L} = \frac{30000000}{4''} \times 0.001615'' = 12115 \text{ lbs.}$$

For $x = l = 1''$ there are

$$y\,l = -0.001252'' \text{ and } A_{l=1''} = 9391 \text{ lbs.}$$

If the pressure in the pin hole were all the constructor has to provide for, the dimensions of the pin and eye-bar might be determined in several ways. In reality, these dimensions are almost fixed, for, as will be shown, to reduce the flexure of the pin, the bearing surface must be short. The rule may be adopted to make the bearing surface B C as long as the eye-bar is thick. In this case, the pressure at B will be 12,115 lbs. whilst at C it is only 9,391 lbs. per square inch for a 3″ pin acted upon by a 3″ × 1″ eye-bar strained to 10,000 lbs. per square inch.

The maximum pressure is 21 per cent. greater than it would have been if uniformly distributed. The depression at B is 0.0016″ and at C 0.0012″, showing the influence of a curvature which hardly can be measured even by very fine tools, and generally would escape notice. The rise in the centre of the pin between H and H will be less than $5 \times (0.0016 - 0.0012) = 0.002''$ —hence it is *unnecessary to provide an upper bearing* in the centre of the casting if the pin is nearly of the proper proportion; the play in the pin hole usually exceeds $\frac{1}{64}$ of an inch, which is more than six times greater than the rise of pin between H and H.

The maximum pressure for the standard bearing length equal to one thickness of the eye-bar was by the foregoing calculation 12,115 lbs.; for a badly fitting pin it would be much larger, since then it is not uniformly distributed over the diameter of the pin, but concentrated at one point. But for a well fitting pin of large dameter the pressure of 12,000 lbs. per square inch is not too large; and for simplicity, it is well to assume that this pressure is uniformly distributed over the diameter of the pin, until at least the effect of "play" in the hole has been directly determined by a large number of experiments on impact.

The later experiments prove conclusively, that wrought-iron after millions of impacts may break on the side where the strain is tensile, but never on the side where the strain is compressive. Experiments recently made in this country as to the crushing strength of wrought-iron support this observation, the ultimate crushing strength having reached 60,000 lbs. per square inch. This quite disproves conclusions from older experiments carried up to ultimate strength, which led to the belief that iron under compression is weaker than under tension; which may perhaps be true for very soft metal. But such iron would not show the same behavior when used in a bridge. A properly proportioned bridge, having no section strained to more than 10,000 lbs. per square inch, will never break from softness of metal in compression, although it may after the passage of millions of trains by the ultimate failure or wearing out of its tension members. This view was always held by the best engineers on the Continent of Europe, and General Morin repeatedly expressed the opinion laid down here.

Fortunately skeleton bridges such as are built by reliable and experienced American engineers, can be calculated; and all good ones are calculated so that no detail is strained nearly to the limit of durability.

To prove how specially erroneous are conclusions derived from Hodgkinson's experiments which refer to alleged differences in the compressive strength of wrought and cast iron, results obtained in France, and illustrated by General Morin, may be quoted.

Two cast-iron beams were made of the same metal and with the same height, length, and area. One of these beams was constructed to suit Hodgkinson's experiments with a heavy tension and a light compression flange, the two being in the ration of 4-7 to 1; the other had two equal flanges, the web was in both beams of the same thickness. The Hodgkinson beams deflected $2\frac{3}{4}$ times more than the plainer one; this ratio according to the theory being exactly as that of the moments of inertia of the cross sections.

The Hodgkinson beam had to stand pressures more than 5 times greater than those of the other beam. The same results were arrived at by testing rolled wrought-iron beams with unequal flanges, which, when reversed, gave precisely the same deflections. Thus,

these two experiments proved that the rules which Mr. Hodgkinson drew from tests up to ultimate strength were useless, to say the least, for parts strained below the elastic limit of the material. Again, to show how unreliable are rules derived from experiments carried up to ultimate strength, those of Mr. Fairbairn on a riveted girder are referred to. They were such as to expose the material to strains nearly in the same manner as for a railroad bridge. The girder broke under a strain of not more than 18,347 lbs. per sq. in. after only 5,175 impacts, and, of course, on the tensile part.

It must be supposed that this girder was of good workmanship, and at least of the average quality of English iron; and we know that a good wrought-iron bar *does not break* under strains of 30,000 lbs. *after* 130,000,000 of impacts.

The girder was repaired; when tested under a strain of 13,000 lbs. per sq. in., it did not break after 2,720,000 impacts. In accordance with new experiments, probably this girder would have broken after a sufficient number of impacts, still, evidently from the first experiments, it actually had *less than* 60 *per cent.* of what was *thought to be the available area.*

Since in such girders generally about 20 per cent. of material is wasted in rivet holes, it may be said, though properly designed and constructed according to the *rules* derived from experiments on *ultimate strength*, that when tested in the same manner as in practice, they have *lost more than half* of the value of their metal. The failure of the Crumlin Viaduct superstructure is another and more direct illustration in proof that experiments to the ultimate strength cannot be relied on in deducing rules for the proportions of pins in bridges.

This failure was due to pins proportioned by a rule derived from experiments on the ultimate shearing strength of rivets. Such rules, applicable to boilers or ships where the ultimate strength must be taken into account, cannot be safely used to determine the proper diameter of a pin. One of their defects is that no allowance is made for pressure in the hole, which frequently is 2½ times the strain calculated to be uniformly distributed over the cross section.

Rivets, on account of friction caused by their heads, transfer a portion of this pressure to the outer surface at the plates they join together, and therefore do not give strikingly bad results in practice.

The same rules cannot apply to pins where no such pressure on the surface takes place.

The deduction of rules for pins from the condition of rivets is not the only empiricism in regard to the former. In Germany, on occasion of the erection of suspension bridges, Engineer Malberg made trials of links which gave results agreeing with those obtained later in England. Though the German proportions were published, it seems they did not receive attention abroad, or else the English experiments would probably not have been made. As far as value is concerned, neither set of trials should be relied on.

Specifications for our bridges require consideration only of a *maximum direct strain* under the heaviest load which the structure may bear. This condition, with reference to pins, can readily be fulfilled by examining analytically the nature of their strains. A pin is nothing but a beam, and since a great variety of experiments, made on beams, prove that within the limits of elasticity the theory adopted is not less correct than that of the law of gravitation to the movements of the planets, what remains to be done is: only to find theoretically the maximum strains at different points of the pin. Recourse, however, was had to empirical researches, and tests were made which could not show the nature of the strains under loads such as occur in practice. Thus the first experimental English rule made no allowance for pressure and flexure, but referred solely for the shearing strain which was supposed to be uniformly distributed over the cross section of the pin. It is plain that at the elastic limit the science of strains ends, since this depends on the principle, "ut tensio sic vis."

Nevertheless this is still frequently overlooked, and especially so in reference to the shearing strain of pins.

The rule, moreover, has been frequently misapplied as to pins of suspension bridge chains, which have been considered as subjected to double shearing, although the outer bars always cause but single shearing, and also not unfrequently to bottom chord pins, where likewise the outside bars cause but single shearing.

This rule regarding exclusively the shearing strength of a pin was used until the failure of the Crumlin Viaduct, and experience gained with suspension bridges

(such as built at Montrose in Scotland, where the pins in a few years cut their way almost through the eyes) caused engineers to make other trials referring to the strength of eyes and the bearing surface of pins. These experiments were with wide and thin bars, as used in suspension bridges, but not in truss bridges, of good design. In this case the eye of the bar, placed between two links or the jaws of the machine, acts on the pin by double shear; the action is the same with a bar as wide as the one tested but one half as thick, placed outside of the bottom chord of a truss bridge.

The new rule deduced, fixing the diameter of the pin from $\frac{2}{3}$ to $\frac{3}{4}$ of the width of the eye bar, contains no provision for the *thickness* of the bar, and applies to the case where the bar is 20 times as wide as thick and the pin is subjected to single shearing. Whether this rule applies to a square bar is more than doubtful for two reasons. First: Under a test up to ultimate strength the pin will flatten, the bearing surface of the eye will be increased and receive a remarkable permanent set, and the now tightly fitting pin will exert a great radial pressure on the pin hole, which causes friction that may be nearly as great as itself, since under high pressure friction increases greatly.

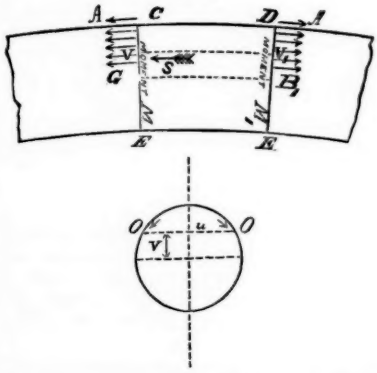
A pin in a bridge is used quite differently; the bearing surface is much less, the pin hole will flatten but little, and the pin would wear out the hole in a comparatively short time if made to conform solely to experiments on the ultimate strength. It seems to follow from such experiments that the pressure on the bearing surface could be considered as uniformly distributed over the semicircular surface instead of through the diameter of the pin. This cannot be correct for a pin which in practice has a play of $\frac{1}{64}$th to $\frac{1}{32}$d of an inch, and which ought not to be pressed more than about 12,000 lbs. per sq. in. Second: The latest English rule does not take account of the thickness of the bar, and of the moment of flexure to which the pin is exposed. This has been already alluded to, and is really the leading point in determining the size of a pin; the dimensions which satisfy this condition will also satisfy the two others.

Having thus explained why experimental reseaches have not as yet established practicable rules for pins, the examination of shearing strains with reference to pins, a subject which has not been sufficiently discussed in many text-books, will be considered.

SHEARING STRAIN IN PINS.

The theory of flexure teaches that the shearing strain is not uniformly distributed over the cross section; consequently the maximum shearing strain must exceed the strains which could exist if uniformly distributed. To show the amount of their difference: Figure 3 represents a part of a bent beam; C E and D E_1 must be two imaginary sections across it, and V V, a surface parallel to the neutral surface G B.

FIG. 3.



The question is what forces keep the body G D V V_1 in equilibrium. The moment of flexure at A generally differs from the moment at B, which, in this examination, is supposed to be the greater. The consequence is that the maximum strain per square inch at D is greater than at C. These strains per square inch at D and C may be represented by the letters A_1 and A.

The strain per square inch in any point V is $A \times \frac{\bar{v}\,G}{\overline{C\,G}}$, since the strains decrease in the same ratio as the point approaches the neutral line. The sum of all the strains of the surface C V is partly counteracted by those of the surface D V, the last named sum being the greater. It consequently needs a shearing force S, acting in the direction of A, to resist the forces in the direction of A_1.

Represent by V any distance G V and by u the width $\overline{v\,v}$, then that for the distance V=VG and the total shearing strain can be represented by

$$S = \frac{A_1 - A}{(C\,G)} \int_{V=G\,V}^{V=G\,C} (v\,u\,d\,v)$$

If the sections C G and D B approach each

other closely, the shearing strain must be considered as being uniformly distributed over the surface VV′ and the strain per square inch will be;

$$\sigma = \frac{S}{vv' \cdot \omega\omega} = \frac{A_1 - A}{vv} \cdot \frac{1}{c\,G \cdot u} \cdot \int_{v=G\,v}^{V=C\,G=a} (u\,v\,d\,v)$$

The values A and A_1 can be derived from their respective moments M and M_1 so that when I represents the moment of inertia of the cross-section of the beam there will be $A_1 = \frac{a}{I} \cdot M_1$ and $A = \frac{a}{I} \cdot M_1$, and the shearing strain per square inch will be:

$$\sigma = \frac{I}{I \cdot u} \cdot \frac{M_1 - M}{v\,v^1} \cdot \int_{v}^{a} (u\,v\,d\,v)$$

and $\frac{M_1 - M}{v\,v^1} = \frac{d\,m}{d\,x} = V =$ the total shearing force for the section C E or D F, so that the shearing strain per square unit will be

$$\sigma = \frac{V}{I\,u} \cdot \int_{v}^{a} (u\,v\,d\,u)$$

For $v = 0$, σ will be a maximum, which is the case for the neutral line itself, whilst the integral decreases to nothing at the point D. For a pin, the section is a circle, and $u^2 + v^2 = d^2$, d being the diameter of the pin, and the maximum shearing strain will be found:

$$\sigma = \frac{4}{3} \frac{V}{(r^2\,\pi)}$$

so that σ is $1\frac{1}{3}$ times larger than if the total shearing force V were uniformly distributed over the cross-section $r^2\,\pi$ of the pin.

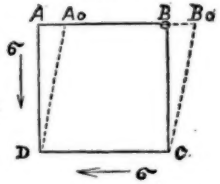
The higher and more accurate examination proves that the shearing strain also is not uniformly distributed over the lines *oo*, that the absolute maximum shearing strain is in the centre of the pin, and is exactly $1\frac{3}{8}$ times larger than it would be if the shearing force were uniformly distributed over the whole section.

There is but a step from the longitudinal to the vertical shearing strain. That both are equal in every point of the beam, (on the pin) can readily be seen by considering the infinitely small hexahedron of Figure 4.

This body could not remain in equilibrium if the horizontal shearing force, σ, were not prevented from turning the figure A B C D around point B, by the vertical shearing force σ, which works with the lever B A, to turn the figure A B C D the other way. A B being = B C = the units, the vertical and horizontal shearing force must be equal. This law is a general one suitable for any body.

Now it has been proved that the shearing maxima strains which act in the centre of a pin, both horizontally and vertically, are $1\frac{3}{8}$ times larger than if it were possible to distribute the total shearing force V uniformly over the cross-section. The value V reaches its maximum just at the facing of the casting, and is equal to the total tension of the eye-bar.

FIG. 4.



How large can the shearing strain σ be, without exceeding the ordinary requirement for iron bridges, that no tensile strain shall be greater than 10,000 lbs. per square inch? In answering this, attention is called to Figure 4.

Shearing strain is but a force which tends to slide an infinitely thin slice of a body along its section, as for instance, the surface A B parallel to C D, into the new position A_0 B_0. The absolute value of the deplacement A A_0 depends on different causes:

Firstly on the shearing strain σ itself.

Secondly on the distance A D between A B and C D, for a surface parallel to C D, midway between A and D would only slide half as far as A B. This law is true, since within the limits of elasticity all displacements increase in direct and single ratio with the lengths.

Thirdly on the nature of the material, so that

$\overline{A\,A}o = \sigma \times A\,D \times \left(\frac{1}{G}\right)$ where $\left(\frac{1}{G}\right)$ is a coefficient dependent on the nature of the material, or it is $\frac{\overline{A\,A}o}{A\,D} = \frac{\sigma}{G}$ tang. angle (A D A *o*).

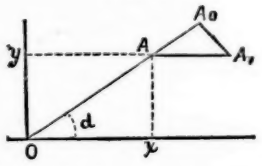
Since σ is a finite value like G, the angle A D A_o is also of a definite value. This angle is the test of shearing strain, so that wherever an angle has changed from right, a pair of shearing strains must have caused it.

The value G must represent a *weight* in order to make $\frac{\sigma}{G}$ an abstract fraction. G is called the modulus of shearing elasticity, and represents the weight which, if the

limits of elasticity would reach thus far, were sufficient to slide a surface so far that the angle A D A_0 would become 45 deg.

A shearing strain can always be resolved into tensions and compressions acting in all possible directions on a point in the interior of a strained body.

FIG. 5.



In Figure 5, O represents a point of a body, A A_1 the shearing deplacement of the infinitely near point A. O x parallel A A_1 is made first axis of the system of coordinates.

The original line O A, by the shearing strain has been changed into O A_1, which is equal to OA plus AA_0, this being the projection of $A.A_1$ on OA.

The shearing strain per square inch being σ, there will be

$$A A_1 = y \cdot \frac{\sigma}{G} \text{ and } A A o = y \cdot \frac{\sigma}{G} \cos \alpha$$

and

$$\frac{A A o}{O A} = \frac{\text{tension}}{\text{modulus}} = \frac{y}{O A} \frac{\sigma}{G} \cos \alpha$$

or

$$T \sin \alpha \cdot \cos \alpha \cdot \frac{E}{G} \sigma$$

This value will be a maximum when α =45 deg., so that Tension maximum

$$= \tfrac{1}{2} \cdot \frac{E}{G c} \cdot \sigma$$

For a perfectly homogeneous body by experiment and calculation, G is found to $=\frac{2}{5}$ E, so that the maximum tension which accompanies any shearing strain in such a body (good iron or steel, but not wood) will $=\frac{1}{2} \cdot \frac{E}{\frac{2}{5} E} - \sigma = \frac{5}{4}, \sigma$. or if the maximum tension is limited to 10,000 lbs. per sq. in., no shearing strain must be greater than 8,000 lbs. per sq. in.

It has been shown that in the centre of any pin the shearing strain is $1\frac{3}{8}$ times greater than if the shearing force were uniformly distributed over the cross section, hence the pin must be proportioned to withstand a uniformly distributed shearing force of $1\frac{3}{8}$ times the actual one; in other words, the shearing strain must only be $\frac{8000}{1\frac{3}{8}}$ lbs.= 5,810 lbs. per sq. in.*

If this condition is observed the tension in the centre of the pin acting at 45 deg. to its axis will be not more than 10,000 lbs. per sq. in.

If the section of the tie bar is "b" by "t" the total shearing force will be $10{,}000 \times b \times t$ and the section of the pin will be $\frac{10000\, b\, t}{5820}$ $= 1.72\ b\ t.$, or the section of the pin must be nearly equal $1\frac{3}{4}$ *the section of the bar.*

This condition determines that in the neutral axis of the pin the shearing strains, tensions, and compressions shall not exceed the maximum tension usually prescribed, of 10,000 lbs. per sq. in.

The rule would apply if another amount, as 12,000 or 15,000, were prescribed. The limit of shearing strain should in such a case be raised correspondingly, by still making the pin section $1\frac{3}{4}$ times the section of the bar.

It will, however, be seen that consideration of the shearing strain alone is not sufficient to properly proportion a pin.

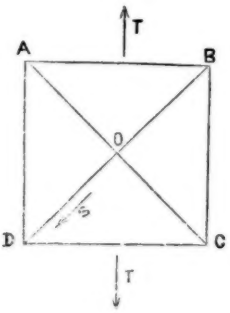
The results obtained thus far depend on the modulus, G being $\frac{2}{5}$ of E for a homogeneous body as good iron or steel. This assertion must now be proved. By purely mathematical investigation, Navier, then Cauchy, Dienger, and others found that any pressure on a perfectly homogeneous body is accompanied by an expansion or lateral tension equal to $\frac{1}{4}$ of the pressure per sq. in., and the tension accompanied by lateral compression equal to $\frac{1}{4}$ the value of the tension. Rude experiments with india-rubber prove the existence of lateral compression or tension, and those made by Wertheim and Regnauld confirm the theory sufficiently, the coefficient differing somewhat with the degree of homogeneity of the bodies under test. For iron, Wertheim found $\frac{1}{4}$, and sometimes a little more, but not so much as to cause a change in the modulus to exceed $1\frac{1}{2}$ per cent. Therefore, without entering into the analytical investigations of Navier, etc., it may be assumed that for well rolled wrought iron the lateral contraction or expansion is $\frac{1}{4}$ the longitudinal tension or pressure.

Fig. 6 represent sone surface of a hexahe-

* The Baltimore Bridge Company make the uniformly distributed shearing strain=6,000 lbs. per sq. in.

dron, which of infinitely small sides is assumed to be acted upon by two tensional forces T, equally distributed over the surfaces indicated in the figure by the lines $\overline{AB}$ and $\overline{CD}$.

FIG. 6.



The sides $\overline{AD}$ and $\overline{BC}$ are extended and the sides $\overline{AB}$ and $\overline{CD}$ compressed. The extension will be $\frac{T}{E}$ BC. the compression $\frac{T}{4E}$ AB, or since AB=BC, the side itself can be assumed as unit, and the extension will be $\frac{T}{E}$ whilst the lateral contraction is $\frac{1}{4}$ of this value.

The angle $\overline{BOC}$ was originally 90 deg., but now it is more and the increase may be represented by the letter ε. If B O C increase, the angles O C B and O B C decrease each one-half the amount of E.

There is consequently after the extension

$$\text{tang}\left(45°-\frac{\varepsilon}{2}\right)=\frac{1-\frac{1}{4}\frac{T}{E}}{1+\frac{T}{E}}=$$

$$\frac{\text{A B after the contraction}}{\text{B C after the extension}},$$

or since ε is a very small angle

$$\frac{\text{tang } 45°-\text{tang }\frac{\varepsilon}{2}}{1+\text{tang } 45°\text{tang}\frac{\varepsilon}{4}}=\frac{1-\frac{\varepsilon}{2}}{1+\frac{\varepsilon}{2}}=\frac{1-\frac{T}{4E}}{1+\frac{T}{E}}$$

From this again (because ε is very small)

$$\left(1-\frac{\varepsilon}{2}\right)\left(1-\frac{\varepsilon}{2}\right)=\left(1-\frac{T}{4E}\right)\left(1-\frac{T}{E}\right)$$

or

$$1-\varepsilon=1-\frac{5}{4}\frac{T}{E} \text{ and } \varepsilon=\frac{5}{4}\frac{T}{E}.$$

The angle A O B having changed its value, there must be a *shearing force along both diagonals.*

This shearing force being S, ε will be $=\frac{S}{G}$ and $\frac{S}{G}=\frac{5}{4}\frac{T}{E}$.

The value S can also be found by a second consideration. If the prism A B D is in equilibrium, the force T, will be counteracted by a shearing force S, and a tensional force perpendicular to diagonal B D.

The projection of the total force acting on the surface, which is represented by the line A B, on the diagonal B D, must equal the total shearing force acting on the surface of the prism represented by line B D, or

$$1\times1\times T\times\cos 45°=\overline{BD}\times1\times S, \text{ or}$$

$$T\times\cos 45°=\frac{1\times S}{\cos 45°} \text{ or } T=2S.$$

The two equations for S combined give the value of G represented by E, so that there is:

$$\frac{S}{G}=\frac{5}{4}\cdot\frac{2S}{E} \text{ or } G=\frac{2}{5}E-$$

This is the equation upon which the rule was based that the section of a pin must be at least $1\frac{3}{4}$ times the section of the bar, to keep the tension caused by the shearing strain below the limit generally prescribed. To many engineers the above deductions may be new, and it is therefore desirable to dwell for a few moments on the conclusions which may be derived therefrom. It has been mentioned that Wertheim and Regnauld made several series of experiments, by which they established that the factor of lateral contraction does most sufficiently correspond with the moduli E and G, as found by tensional and torsional experiments.

The theory of strains has received very valuable proofs by Chief Engineer Woehler, in Germany. He made experiments on impact, on tension, compression, torsion, etc., during 12 years. He first established the law that any material may be broken by repeating sufficiently often extensions, which, however, cause strains below the breaking point, and he then determined certain limits of strain within which the material did not break. Further experiments on torsion and other more direct chearing strains confirmed the same law, but established that this limit must necessarily be lower then for direct strains.

We may call these limits the "limits of durability."

Cast-steel, cut from railway axles furnish-

ed by Krupp, has not broken after 40,000,000 impacts, straining the material transversely to 53,000 lbs. Nor could this steel be broken by any number of impacts causing shearing strains of 42,000 lbs. per square inch. All strains higher than these produced rupture after a sufficient number of impacts; and there seemed to exist a certain relation between the number of impacts and the value of the strain. We may therefore call 53,000 lbs. the limit of durability for tensile, and 42,000 lbs. the limit for shearing strain of the class of steel experimented on.

According to theory, the ratio between both limits ought to be as 1 : 0.800, whilst in reality it was as 1 : 0.793.

The tensile modulus of this steel was experimented on, and fixed at 28,725,000 lbs., while the shearing modulus, found by very careful torsional experiments, was 11,237,000 lbs. Their ratio, according to theory, ought to be as 5 : 2.—when the result of the experiment proved it to be as 5 : 1.95.

The quoted results refer only to a very small part of the experiments, which were extended to copper, and wrought and cast-iron of different makes; all gave results in good harmony with theory, and as they were made to test the material in the same manner as in practice, they prove that, within the limits for which the theory holds good, we can well rely on it with this proviso—that for riveted, forged or machine-worked parts, experiments should be made of each class of material, by which alone a correct idea as to their strength and endurance can be formed. The older experiments, made on strains beyond the limits of durability of the material, or not with acting in the same manner as in practice, or carried to the ultimate point of failure, could not possibly lead to any law or reliable formula, because the phenomena beyond the elastic limit cannot be followed up by even the highest analysis, and possibly do not conform to any law.

Frequently, as a consequence of the older views, the effects of shearing, torsional, compressive, and tensile strains and strength, are spoken of as so many different phenomena without relation to each other, while in reality in every point of any strained body there exist shearing, tensile, and compressive strains at the same time.

Referring to the object of this paper, it may be added that experiments on the ultimate shearing strength show that the results greatly depend on the way they are obtained, in some cases the shearing strength being found as great as the tensile strength, and in other cases only two-thirds of it.

If the greatest tension in a wrought-iron bridge is assumed at 10,000 lbs. per square inch, the greatest shearing strain ought not to exceed 8,000 lbs. This is far within the limit of durability of good iron under tension, which after 132,000,000 of impacts was established at 33,000 lbs. per square inch.

Having now determined the fundamental laws of elasticity which enter into the problem of the shearing strains in a pin, and also having given the data necessary in estimating the maximum pressure that can be allowed in the pin-hole, a more important consideration remains, the nature of the strain caused by the moment of flexure of the pin is still to be examined.

Attention is called to Figure 1, representing the strains upon a pin either in a top chord of a truss bridge, at the exterior links of a bottom chord, or of chain suspension bridges. The question is where to find the maximum moment of flexure?

It is a very common mistake to assume that the maximum moment is in section F B, when, instead, it occurs in section H C. For by reversing Fig. 1 it will be seen that the problem is the same as if a beam, G G, were loaded on both sides from G to H, leaving a space H H unloaded, and that the two eye-bars form the supports of such a beam.

Consequently the moment must have a constant value from H to H, and the maximum moment must exist in any section of the pin between H and H.

The pressure on B C for the present purpose can be considered as uniformly distributed, and the strain of the eye-bar assumed as being concentrated in D, which is in the middle of line M G. The reaction likewise is then concentrated in the middle of B C, which, according to previous considerations, is made to be equal to M G.

In fact the centre of the reactionary forces is a little closer to B than to C, but the difference is very small, as long as the bearing is not longer than the bar is thick.

This supposition leads to the smallest possible pin, and when the bearing surface is made longer, the pin must be stronger, while the pressure in the pin, hole at the

same time decreases, but is less uniformly distributed.

The moment of flexure of the pin in the section H C, is $= P\left(\frac{M G}{2} + G H\right)$ less $P.\frac{G H}{2}$, or since G H was made $=$ M G there will be the maximum moment $=$ P . M G $=$ the strain of the eye-bar multiplied by the thickness of the bar as lever.

The exact value of the moment can be found by determining the value $E I \frac{d y^2}{d x^2}$ of the curve B C, for $x = l =$ B C of which the equation has been developed.

This value for *any* length P of B C would give the exact moment and strain which a pin has to bear, its diameter being assumed previously

The value $P \frac{M G + G H}{2}$ is much larger than it would have been obtained had section F B been the one examined. Then the moment would have been only $P.\frac{M G}{2}$, which is less by $P.\frac{G H}{2}$ than the actual maximum moment.

Under the assumption that M G $=$ G H the error is 100 per cent. and when G H> M G it is still greater. If the size of the pin were calculated under this erroneous supposition, the actual strain would be twice or more *than twice as large* as was intended. There is no shearing strain and no compression by reaction in the section C H and the tension in the uppermost fibres could be used for the determination of the size of pins.

The well known elements of flexure prescribe that there must be, for $l = t : \frac{S}{4}\left(\frac{d}{2}\right)^3 .3.14 = P\,t$, or since $P = b \times t \times 10000$ lbs. and when S is fixed at 10000 lbs. per sq. in. $\frac{d^3}{32} . 3.14 = b \times t^2$ and $d^3 = 10.18 . b\ t^2$.

If $b = 4t$ $d = t^3\sqrt{40.72} = 3.44\,t = 0.86$ width of bar.

$b = 3t$ $d = t^3\sqrt{30.54} = 3.18\,t = 1.06$ " "

$b = 2\,t$ $d = t^2\sqrt{20.36} = 2.73\,t = 1.36$ " "

$b = t$ $d = \sqrt[3]{10.18} = 2.16\,t = 2.16$ " "

$b = t$ (round bar) $d = t\ \sqrt[3]{8} = 2.00\,t = 2.00$ thickness of bar.

These sizes of pins are so large as to exclude entirely the consideration of shearing strain and of pressure in the pin-hole, but it may be justifiable to permit greater strains from flexure than has been prescribed for the maximum tension of the tie-bar. Indeed there are reasons for this consideration. 1st. It is impossible to equally strain all bottom chord bars to exactly the specified limit; some bars will receive tension exceeding 10,000 lbs. per square inch, as will be explained hereafter. Also when several bars are fixed to the same pin it cannot be expected that they severally will have equal moduli of elasticity, hence the prescribed maximum of 10,000 lbs. may be exceeded.

2d. The eye-bars have been shaped by a process of manufacture, which under all circumstances somewhat impairs the uniform quality of the iron.

3d. A pin has not been exposed to fire after having been rolled; if turned to size with good machinery, and by a skilful workman, its quality has not been altered; hence the iron of which it is made is more reliable than that of any other part of the structure.

Under these suppositions, it is thought safe to permit a maximum tension of 12,000 lbs. per square inch, which is not more than the maximum pressure in the pin-hole as determined in the first part of this paper.

The results of the calculation brought to practical dimensions, are represented in the following table:

Width of bar	b	4″	3″	2″ 1″ 1″.
Thickness of bar..	t	1″	1″	1″ 1 square 1 round.
Diameter of pin...	d	3¼″	3″	2½″ 2″ 1¾″
Ratio of $d : b$		0.8,	1.0,	1¼ to 1⅜, 2, 1⅜ to 1⅝

The maximum shearing strain of these pins is 6,600 lbs. per square inch—the minimum about 5,000 lbs.

According to these results the old rule of $\frac{d}{b} = \frac{3}{4}$ is only admissible for bars with thickness ¼ of their width, or less than this. The use of this rule for a square bar would permit a maximum strain of more than 60,000 lbs. per square inch, if the conditions did not change by the action of the nut when a permanent set takes place, and a pin of 1½″ diameter for a 2″ × 1″ bar, would permit a maximum tension of nearly 50,000 lbs.

These two examples are sufficient to show the importance of properly proportioned pins, and that the best American bridge constructors are wise in using dimensions varying but little from those found above.*

Indeed for a considerable time the more scientific engineers of this country have strengthened by degrees their bridge con-

* Mr. Thos. C. Clarke, of Philadelphia, stated in a recent letter to the American Society of Civil Engineers, that in the bridges of the Phœnix Bridge Co., nearly the same diameters as given in the last table are used.

nections, and by combining practical experience with theoretical considerations the theoretical dimensions have been nearly reached. European engineers by using riveted work have not had an opportunity to obtain this result. This affords a reason why in many late books the subject of pins is not treated more scientifically.

The practical bridge builder, when designing a structure, sometimes finds it difficult to fulfil the conditions of theory and manufacture which more or less contradict each other. However, the heavier tie bars which carry the greater part of the dead load are not so much influenced by the live load, which is the really destructive element, while the pins of the lighter bars, near the centre of the top chord, are generally stronger than necessary.

The diameter of top chord pins can be reduced by making them what is called double shearing, a bearing being placed on each side of each bar; the diameter can then be determined as if the bar had only $\frac{6}{10}$ at its thickness.

It has been seen how necessary it is to use the proper size of pin in the top chords, which is more especially true for pins bearing more than one bar. In this case the sum of the bending moments produced by the several bars must be introduced in the formula for the tensile strain by flexure.

Great care is also required in properly proportioning the pins of bottom chords of bridges. Generally here the pin takes hold of the post, directly to it are attached the ties, outside of which the bottom bars are arranged. Here the greatest moment of the pin is near the bottom bar next to the tie. It is an accumulation arising from the sometimes great number of bars. In order to form a more precise idea of the strains which may arise, it may be as well to examine a practical example.

Suppose the three equally strained bottom bars 3 in.$\times$1 in., 3 bars 3 in.$\times 1\frac{1}{4}$ in., and a tie 3 in.$\times$1 in. are on the same pin on one side of the post of the bridge. The maximum moment will be 5.1 in.$\times$10,000 lbs., and the maximum tensional strain by flexure 12,100 lbs., whilst the pressure in the pin hole will be found to be 8,570 lbs, resulting in a tension of 14,200 lbs.

Some bridge-builders use square bars, with pins not much larger than the thickness of the bar.

Suppose, in reference to the above example, that three 2 in. square bottom bars were counteracted by three $1\frac{3}{4}$ in. square bars and the tie. For a 3 in. pin the tensile strain by flexure would amount to 25,000 lbs. Of course neither this nor the above strain of 14,200 lbs. will really exist in the pin. The fact will be that the pins bend a little toward the centre of the bridge, and the bars near to the centre line of the bottom chord will bear a greater share of the chord strain, relieving the outer bars. The difference will be the greater, the smaller the pin; the greater the difference in size of bars, the thicker the bars, and the shorter will be the panels.

The difficulty of reducing the strains of bottom pins to the strain of the bars increases with the magnitude of the bridge, and may partly be met by increasing the number of flat and thin bars, making up for the difference in tension in two adjoining panels rather by the number than by the size of the bars, and especially by using the proper size of pin.

Another way to meet the difficulty consists in creating two centre lines in the bottom chord, by placing a proper number of chord bars between the ties, by using two posts, or by constructing a properly built post foot. For small bridges these costly arrangements can be dispensed with. Flat bars, in preference to round or square ones, are in all cases to be recommended. The Baltimore Bridge Company, for instance, always use such, and it seems that other constructors have recently adopted the same, to the exclusion of round bars.

Pins used in chain suspension bridges, the bars being all of equal section, have to resist only a small moment; their proportions follow the rule for top pins.

As a conclusion to which the foregoing examination perhaps has led, it may be mentioned that it is easier to calculate the general strains of skeleton structures than to design details, which, satisfying the practical demands of economical, speedy, and reliable manufacture, are also in harmony with the more subtle ones concerning their proportions.

A corps of engineers are making a survey of a new railroad route from the mouth of Redbank to Brady's Bend, on the west side of the river. This road is intended to reach the Butler County oil fields and connect with the Bennett's Branch road. It is projected by the Pennsylvania R. R. Co.

UNIFORMITY OF STRAIN.

From "The Engineer."

If we were to imagine a single fibre of iron, steel, or other material adapted for undergoing tensile strain, secured at one end to a fixed support, and having a weight suspended at the other, we should have the nearest solution of the problem of "uniformity of strain" to which it would be possible to attain. Pushing this argument a little further, it may be assumed analogically that the nearer we approach to these conditions with respect to any rod or bar of iron, the nearer also are we to the solution of the problem in question. In other words, the smaller the rod or bar the more uniform the strain upon it, and indirectly the greater its strength. Now it is known as a fact that small rods and bars are proportionally stronger than those of comparatively larger dimensions. The reason alleged for this apparent discrepancy is that the iron is of better quality, that is, that a superior degree of homogeneity can be imparted in the process of manufacture to the smaller scantlings. This, no doubt, is true, but at the same time it is open to discussion whether this is the sole cause of the proportional increase of strength. As all bars must be broken in order to determine the ultimate strain they will bear per inch of sectional area, is it not probable that the extra strength exhibited by those of the smaller scantlings may be in some measure due to the fact that the principle of uniformity of strain is more fully carried out in their instance than in that of bars of larger size? The nearest practical approach to our illustration of the single fibre is a wire, and the tensile strength of iron and steel wire is enormously in excess of that of either rods or bars. The conclusion to be drawn from this statement is that a number of wires bound together will be a great deal stronger than any rod or bar having the same aggregate sectional area, and will therefore constitute the best form in which the material can be put when it is subjected to a strain of a tensile character. Under certain circumstances so they will, provided always that in every instance the principle of uniformity of stress can be practically carried out. Since the strength of not only isolated rods and bars, but also of the various members of girders and trusses, considered as entire structures, very much depends upon the fulfilment of this condition, it is not to be wondered that engineers have paid considerable attention to the subject, more particularly of late years, when examples of iron construction have been greatly increased in both number and magnitude.

When a homogeneous rod or bar of iron is exposed to a tensile strain the separate resistances of all its fibres may be regarded as acting in parallel planes, and may be replaced by a single resulting resistance equal to the sum of the components, and acting at its centre of gravity. It is obvious whatever may be done with a number of independent wires merely bound or clipped together, that it is not possible to seize or grip the individual fibres of a rod or bar in order to subject them all to the same uniform strain. Consequently the only course open, with the view of fulfilling the required condition, is to cause the strain to act at the point of the application of the resultant of all the resisting forces, that is at the centre of gravity of the bar. Theoretically this suffices, but practically, in numerous instances, it certainly does not. In wide bars and plates, in which the action of the strain is simply reduced to that of a single force applied at one point, the parts nearer the line or direction of the strain are undoubtedly strained more severely than those situated at a greater distance from it. No better illustration of the value of the principle of uniform distribution of strain can be found than in an ordinary butt joint. Any thickness may be given to the wrappers, and any number of rivets may be inserted, but the joint which will stand the highest breaking weight in the testing machine will be that in which each cross section is designed in accordance with the principle laid down.

The importance of securing uniformity of strain in the various members of a girder was not kept sufficiently in view in the early designs of railway bridges. At the present time there is little doubt but that some examples of these structures which are supposed, according to calculation, to be subject to a strain of 5 or 6 tons only to the square inch, are in reality in some of their parts working up to nearly double that amount. In all girders and bridges it is

essential that any particular strain should pass accurately through the axes of the members which are resisting that strain, and if this is not the case it is the fault of the designer. It is on account of the non-fulfilment of these conditions that objection has been taken to the trough section of flanges for girders, such as those of the Charing Cross Bridge. This particular section of flange does not carry out the principle in question, although it might be adapted to do so to some extent if the intersections of the bars of the side girders were differently and better arranged. Were the diagonal bars so adjusted in position that the lines representing the longitudinal axis of every pair, should intersect the axis of gravity of the flange in the same point, a much nearer approach would be made to the desired conditions. As already mentioned, the total forces or strains induced in the bars may be regarded as concentrated in their resultants, and acting in the direction of their longitudinal axes. At the point at which these resultants meet, that is at their common intersection with the flange, they are resolved horizontally, and if the point is situated in the axis of gravity of the flange, this horizontal resultant will act along that line. The greater the distance, or in other words the greater the want of coincidence between the point of intersection and the axis of gravity of the flange, the greater will be the inequality in the distribution of strain; but while there is a manifest loss of economy in not paying regard to this detail in the designing of trussed girders, the detrimental effects due to the absence of coincidence in the lines of the strains and the axial lines of the members upon which they act, are not so serious as some imagine. In the first place, the flange has to resist not merely the horizontal strains due to the resistance of those in the bars of the web, but also the vertical components as well. A flange which is designed to fulfil only one of the requirements is defective. As a rule, it is advantageous to place the greater portion of the metal in a flange in the horizontal parts, not in the sides, and moreover the adoption of the single T section in the trough affords facilities for attaching the diagonal bars, which must not be overlooked. It must not be forgotten that the direction of the strains in a girder or truss must be regarded as a whole, and it is by no means certain that a line laid down on paper to represent the line of strain upon any particular member will accurately represent that strain when the structure is erected and subjected to its regular working load. In a bridge or roof which is well proportioned, and in which the principles mentioned are pretty closely adhered to, there is a tendency in the structure itself when put under its load to adjust the direction of the strains in the right manner. This self-adjusting tendency will not happen when the structure is badly designed, but there is a great difference between a bridge or roof which is radically wrong in design and one in which the dictates of theory are carried to an extreme, and possibly an absurd limit.

The effect of straining plates in directions which do not pass through their centre of gravity is well shown by a series of experiments made some years ago by Mr. W. H. Barton. The plates were 2 ft. in length, 6 in. width, and $\frac{1}{4}$ in. in thickness. Each plate had two small ribs cast upon it, at distances of 12 in. apart, and in these ribs six holes were made in which to insert delicate measuring instruments. It was found that the mean elongation of the plates was the same at whatever part of the plate the weight was applied, but that when the strain was applied along the line of edge, it produced an extension along that side, and corresponding compression on the other side. It was also ascertained that an angular movement took place which varied as the weight or strain multiplied by the distance of the line of application of the strain from the centre of gravity. If the plate were free to move under the strain it would exhibit a degree of weakness which would not be displayed if the direction of the strain coincided with its centre of gravity, since in that case the multiplier of the angular movement would equal zero. The difference to be observed in drawing a comparison between these plates and the flange of a girder is, that the former may be regarded as separate or detached parts, whereas the flange is a continuous member in itself, one portion of it might probably, and no doubt does, correct any undue strain in another. There is a counterbalancing action at work in the flange of a girder which does not exist in a single isolated bar or plate. On the other hand, the advantage of so adjusting the relative members of a girder or truss, that the principle of uniformity of strain may be adhered to should never be lost sight of, but, on the

other, certain practical considerations must be attended to as well. It is bad engineering to totally neglect practical requirements in the attempt to carry out theoretical measures which are as likely as not to prove abortive.

CONTRIBUTIONS TO SPECTROSCOPY.

By Prof. A. K. EATON.

Written for Van Nostrand's Magazine.

The following illustrations are presented as the readiest method of answering inquiries that have reached me as to the position of the prisms, etc., in the experiments described in my brief note, in the July number of the Magazine. I also describe a new form of prism that I have devised, and the use made of it.

Fig. 1.

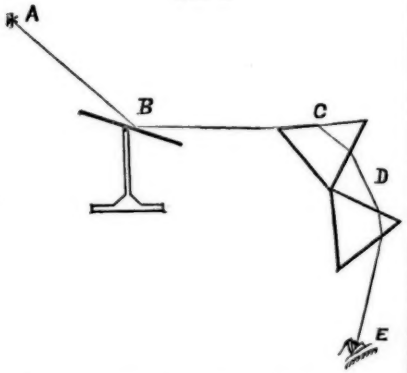
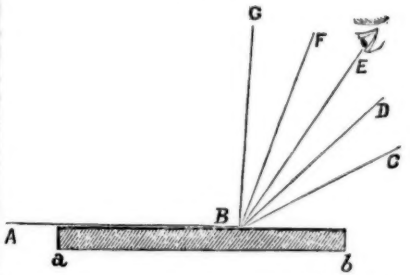


Fig. 1 represents the position of the prisms in producing a pure spectrum from direct solar light. I prefer to make use of a mirror B, as a means of rendering the sun's rays horizontal, as, in that case, the prisms are easily supported in their requisite relative positions. The ray may, however, be taken directly from the sun, but the manipulation of the prisms then becomes troublesome. The incident ray, B C, enters the face of the first prism at an angle of very nearly 90 deg. to the perpendicular. If only one prism be used, the eye will be placed at D; and, with any ordinary flint-glass prism of 60 deg. refracting angle, the observer can readily separate b_1 and b_2 of the b group with two prisms and the eye at E; the main components of the D band are readily resolved. The second prism is so placed that the mean ray will emerge at the angle of minimum deviation.

In making use of the diffraction plate, without slit or collimating lens, the ray may be taken directly from the sun; but it is much more satisfactory to render it horizontal by means of a mirror as in the prism experiment. In Fig. 2 we have the incident ray A B striking the diffraction plate $a\ b$ at an angle of nearly 90 deg. to the perpendi-

Fig. 2.



cular. The eye placed successively at C, D, E, F, and G, will see the spectra of the 1st, 2d, 3d, 4th, and 5th orders. With the exception of the first, the spectra of the different orders are more or less mixed by overlapping, but it does not affect the central portions of the spectra. D_1 and D_2 are readily resolved in all the spectra except the 1st, and the nickel line between these is easily seen by the aid of a telescope of very low power. This experiments were conducted with a diffraction plate of speculum metal.

Fig. 3.

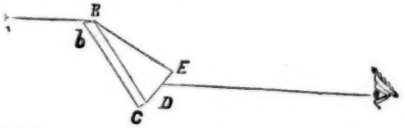


Fig. 3 represents a direct vision prism, consisting of a very dense flint prism B D F, upon which is cemented a thin plate of crown glass, the end of which, b B, is cut

and polished to the angle represented. This prism, without slit or collimator, defines the Fraunhofer lines sharply when the direct light of the sun is used, but the diffuse light of the sky does not give lines of any sharpness. By changing the angle of the polished end of the crown glass *b* B, so that it is right angled to the surface of the plate, and receiving the ray so that it is totally reflected from the surface *b* C, after entering the end of the plate, I avoid the difficulty of loss of light and define the lines; but in this case it is no longer a direct vision prism.

I have succeeded, in the prosecution of these experiments, in producing a prism for the direct-vision spectroscope, which has obvious advantages, in point of simplicity and cheapness of construction, over the complicated combinations in general use. It involves the use of the slit and collimating lens, however, as in the ordinary forms.

FIG. 4.

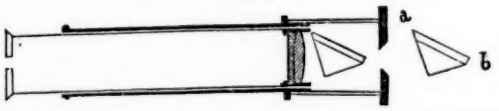


Fig. 4 represents the prism, also the mode of applying it in the small hand spectroscope. It consists of a prism of flint glass, upon the surface (*a b*) of which is cemented a plate of crown glass. The end of the plate at *b* is cut and polished, forming an angle of 90 deg. with the surface of the plate. The outer surface of the plate is rough.

This prism, with slit and collimating lens, arranged as in the figure, gives a spectrum that compares favorably with that of Browning's "Miniature Spectroscope," with 2 flint and 3 crown prisms in combination.

If two of these prisms be used, the second being placed behind the first in the position of Fig. 4, the spectrum is doubled in length.

This form of prism seems to be of great promise. Thus far I have only applied it in the construction of a two-prism small hand spectroscope. It is evidently not limited to this use.

HOOSAC TUNNEL.—Says the "Boston Advertiser": During the month of April the aggregate length of tunnel opened in the Hoosac Mountain was 299 ft., of which 156 ft. were from the west shaft eastward, and 136 ft. from the central shaft westward. The work done from the central shaft was the best month's progress ever made in the tunnel. There remained on the 1st of May but 1,939 ft. to be pierced, the total progress to that date being 23,092 ft. Should the present rate of progress be continued we may confidently expect that there will be a hole through the mountain by the 10th of next November, and in a very few months thereafter the cars may be running through it from end to end. Some singular facts are reported in relation to the circulation of air within the tunnel. When the opening was first made from the central shaft to the east heading, there was a strong draft of air inward and upward, so that at times an unprotected light would be at once extinguished by the wind. But as the temperature has increased, the draft has gradually diminished until it is now practically reduced to nothing. The slight current observed varies both in strength and in direction with the temperature. The correspondent referred to says that "during the night the draft is upward through the shaft, and during the day as the air becomes warm, the same process takes place as above mentioned. The results of the downward shaft give interesting information. A light can be seen the entire length of the shaft, a depth of 1,030 ft. The timbering is visible about one-half of the distance down, giving a more frightful cast to the notorious place than ever before. The daylight also penetrates to the bottom of the shaft, a fact which has never before been recorded." These are very curious facts, and they will doubtless attract the attention of scientific men. It is not, however, to be assumed that they will have any important bearing on the matter of ventilating the tunnel when in use. The experience of the Mont Cenis tunnel shows that there is no difficulty in the operation of a still longer tunnel without shafts.

STEAM-BOILERS.*

From the "English Mechanic."

There is one part of this book which especially commends itself to the attention of steam-users—namely, the consumption of fuel; but there is scarcely a page in it that does not contain something the proprietor of a steam-boiler will find it to his interest to know; and if we venture to say that boilermakers, too, might re-learn from it some lessons they appear to have forgotten, we shall have given a tolerably comprehensive idea of its contents. Mr. Wilson, who modestly says that his book does not pretend to give any new facts or opinions on the subject of which it treats, was formerly Inspector for the Manchester Steam-Users' Association, and, in pursuance of his duty, has naturally been brought face to face with many of the defects exhibited by different examples of boiler construction, and has gathered together from various sources information virtually inaccessible to the majority of those who are engaged in, or affected by, the application of steam. It is not very probable that the nineteenth century will witness the advent of a power which will entirely supersede steam; and even if one of those marvellous inventions which we have often had occasion to mention—and to ridicule—were perfected to-morrow, the time which must necessarily elapse before it could replace all the steam-engines in Great Britain would necessarily be of so long duration that attention might still be profitably turned towards the improvement of the existing machinery for utilizing the power latent in our coal. But even this improvement would seem to lie in one direction, and in a rather narrow compass. We have arrived at the use of steel for our boilers, and have consequently reached our limit, as far as strength of material is concerned; it is, therefore, principally to an improved form of boiler that we must now look for further advance towards a perfection which can never be reached. We have already taken some strides in this direction, and we have our spherical, tubulous, and other boilers of the "patent-safety" class, made in units, segments, or sections, and employing in many cases the same description of metal as found favor with the early pioneers in the battle with steam. These inventors, when their granite boilers were unsuitable, employed a hollow sphere of cast-iron, and placed it over a fire. This shape soon gave way to the vertical cylinder, and the latter to the horizontal oblong boiler; when Watt introduced his "wagon" shape, which was tolerably well adapted for the pressure then employed, and specimens of which are, we believe, still at work in some parts of the country. From the wagon species the "haystack" and the "balloon" shape were evolved, and many of them must be still in use, if we may judge from the fact that we scarcely ever receive a "report" from the Manchester Steam-users' Association without finding one or the other figuring as principal performer in an explosion drama or tragedy. These boilers often have a diameter of 15 or 20 ft., and although safe enough when new for the pressure they usually carry, from 5 lbs. to 15 lbs., often when old explode with only about 5 lbs. above the atmospheric pressure. Happily these terribly wasteful means of utilizing power are being speedily replaced, owing to the conviction of their owners that a pressure of 40 or 50 lbs. is more economical than one of 7 or 10 lbs., and that coals, if not scarce in their neighborhood, are beginning to be worth money. The next boiler to make its appearance was the externally-fired horizontal cylindrical, with hemispherical ends (the egg-ender), or with flat or cambered ends, through which a flue passed to lead the hot gases to the chimney, and thus increased the heating surface. This latter device naturally led to the placing of the furnace within the tube, and the introduction of the Cornish type—a type which, in spite of the numerous claimants for boiler honors, is likely to hold its own for many years to come, or at all events till pressures of 150 to 300 lbs. become the rule. The Lancashire boiler is of course only a double-flued Cornish, and none of the numerous modifications of the type have succeeded in beating the older model out of the field; the two furnaces were made to combine in one flue-tube beyond their bridge, called the "Breeches" boiler; the flue has also been blanked off behind the bridge, and taken

* A Treatise on Steam-Boilers: their Strength, Construction, and Economical Working. By ROBERT WILSON. London: Lockwood and Co.

out at the side, or out at the bottom, as in the "patent downtake" (p. 353, vol. xvi.), to re-enter the shell from the back end of the boiler, in the form of a horse-shoe tube; but the only modifications that are really improvements are those in which water-tubes are placed across the flue tubes, and, other things being equal, the multitubular variation of the Cornish. The French, or Elephant boiler, has a couple of cylindrical heaters, connected by water-tubes to the main shell above. They are of course always full of water, and are completely surrounded by flame and hot gases. It is after this type, though certainly a long way after, that Sir Wm. Fairbairn's new boiler is modelled; a boiler which may be looked upon as the prototype of the future apparatus for raising steam. Finally, we have the vertical, most numerous of all in its varieties, and each very wasteful of fuel; the Rastrick, specially adapted for iron works, a vertical cylinder with a central flue and horizontal tubes to convey the hot gases from blast-furnaces and other places where heat would otherwise be wasted; the locomotive type, very serviceable where space is limited; and, last of all, the new "patent safety" boilers, made up of units, segments, and sections, which are only at present beginning, so to speak, to feel their feet. Theoretically, these boilers are the best, because they expose the greatest amount of heating surface, are believed to be inexplosible, and make steam quickly, with a proper circulation of the water. Doubtless improvements suggested by experience will spedily be made in them; but at present in practice it must be confessed that they require their water to be specially prepared by having the solid matter removed, if the best continuous results are to be obtained, while a few of the varieties are obviously defective in construction, as some of the reports of the inspection companies clearly show. The difficulties attendant upon their use, however, are not insurmountable, and we are prepared to see a great improvement in this type of steam-boiler in the immediate future.

We do not intend to follow Mr. Wilson through the chapters he devotes to the consideration of the strength of different shaped boilers and the directions and force of the steam pressures within them; suffice it to say that the accepted rules are clearly adopted and explained without unnecessary complication. The portion of the book which treats of this part of the subject and also of the properties of the various kinds of metal used in the construction of boilers, contains much information of the first importance to makers and would-be inventors. With regard to the shape of the rivets, Mr. Wilson is decidedly in favor of the snap or cup-shaped head, and not without reason. The conical head is very frequently made too flat, and is often so brittle as to be easily detached by a single blow, besides offering the minimum of material to withstand corrosion. Machine-riveting would appear to be in favor with Mr. Wilson, but we think that, when properly done, hand-riveting is the best. Unfortunately, it is very rare that it is properly done, either from lack of skill or carelessness on the part of the workman. It is no doubt true that machine-riveting upsets the rivet and closes the hole better than hand-riveting, and, no doubt, gives superior work for girder-riveting; but there is always the possible defect that the plates may not be brought into close contact, and that the rivet itself may be squeezed out between the plates, and cause a permanent separation. On the contrary, with hand-riveting, when properly done, and it is only of the best skilled workmanship that we are speaking, the plates are invariably brought close together, and the rivet being struck fair in the centre of the point, fills the hole as well as in machine-work. It is a point, however, whether the subsequent cold hammering, especially with the conical-headed rivet, does not cause deterioration of the metal although this must depend essentially on the quality of the iron. We are inclined to think, though, that the best system of riveting is that which reduces to the minimum the amount of caulking necessary; for careless caulking is answerable primarily for many disasters, though the practice prevailing in many good works of preparing the lapping edges of the plates undoubtedly goes a long way towards reducing the amount of caulking necessary, and enabling the riveting-machine to produce better work. With respect to the vexed question of drilled *versus* punched holes, Mr. Wilson makes some sensible remarks. We have, ourselves, frequently endeavored to point out that the question which is the best method depends entirely on the character of the metal in which the holes are to be made. If the boiler is to be made of steel-plates, drilling is undoubtedly indicated; but wrought

iron-plates ought to be capable of withstanding the effect of the punch uninjured, or they are not fit for boiler-making. The majority of the experiments made in this connection, however, appear to show that, taking all kinds of work, drilled plates are stronger than those in which the holes are punched, but that rivets offer more resistance to shearing strain in punched holes than in drilled. The experiments on this point are detailed by Mr. Wilson, and also the conclusions arrived at by Sir W. Fairbairn and others, with regard to the relative strength of lap and butt-joints. The chapter, too, on the construction of boilers is replete with information with regard to stays, hoops, or strengthening-rings, the arrangement of plates, and the fastenings of tubes.

The introduction of the feed-water into boilers, is a subject deserving of more attenthan it usually receives. In most of the Cornish type it is usually delivered near the bottom, because it is thought that, by putting it in near the water-level, the furnace-crown seams are liable to be started, and that the admission of cold water near the surface may tend to condense the steam. Mr. Wilson, however, points out that in most internally fired boilers there is always a considerable amount of dead-water at the bottom, which is, comparatively speaking, cold, and it is therefore opposed to common sense to put more cold water in the very place where the coldest water in the boiler tends to remain. "By introducing it at a higher point in the boiler the comparatively cold water naturally tends to descend, in consequence of its superior gravity, and promotes the circulation by displacement. In its descent, which may be retarded by the circulation, the water becomes heated, and thus tends to equalize the temperature above and below, and thereby lessens the inequality between the temperatures of the top and bottom of the shell, which is so destructive to the boiler." He therefore advises that, in internally-fired boilers, the feed should enter through a horizontal perforated pipe, placed just above the lowest water level—a plan which not only effectively distributes the cold water, but, if the pipe is a long one, appreciably raises its temperature. Fusible plugs come in for a little animadversion from Mr. Wilson, who thinks their efficiency has been much overrated. The rationale of these plugs is too well known to need much explanation. They are inserted in the furnace-crown, and are made of an alloy which is supposed to melt as soon as it becomes unprotected by water. As a matter of fact, however, it would appear that the alloy undergoes some change during long exposure to heat, and apart from any protection it may derive from the coat of soot or dirt which generally accummulates on it, fails to melt according to calculation. On the other hand, it may melt without liberating the steam, in consequence of the scale having acquired such a thickness as to withstand the steam-pressure till the plates of the crown are burnt and the mischief done; a similar result will of course ensue, even when there is abundance of water; and the plugs are so far useful in this case, that they indicate the dangerous thickness to which the incrustation has reached. It is, therefore, found necessary to frequently renew these fusible plugs, if advantage is to be taken of the security which they are supposed to afford; but it is important to remember that the area of the opening left by the melted plug should be considerable; for, apart from the fact that a small hole will not materially reduce the pressure in a boiler, a mere jet of steam passing over glowing coals is decomposed, and the fierceness of the fire is in consequence considerably increased. Incrustation is treated almost exhaustively, and if the conclusions arrived at are vague and unsatisfactory, that is nothing more than might be expected. All the tried and suggested remedies are mentioned by Mr. Wilson except tannate of soda, or Kalignoid, as we find it is called in this country; but he considers that the simplest plan of preventing incrustation, and one that is withal the most reliable, is to allow the boiler to cool as gradually as possible, and to stand with the cold water in for a few days before it is emptied and thoroughly cleansed. The operation would require repeating at intervals of a few days, and would necessitate the employment of a spare boiler—two conditions which are utterly at variance with the business habits of an average steam-user. Mr. Wilson also alludes to the attempts which have been made to employ electricity to prevent incrustation, and his opinion of its merits may be gathered from the following sentences:—"That this means of removing scale has been stated to be successful on what should be good authority, there can be no doubt. But in more than one case it has been found that gold and

not electricity was the agent to which the incrustation yielded. Any unscrupulous boiler attendant, by suddenly cooling the plates when emptying the boiler, can produce results which he can ascribe to the efficacy of any kind of anti-incrustator it may be to his interest to extol." The chapter on wear and tear, which includes the proper setting of boilers, contains information which should be known to every boiler-user as well as maker; and on the important and rather vexed question of testing, Mr. Wilson bears witness to the advantages of the hydraulic test. "Many cases of dangerous defects, which the strictest scrutiny of the completed boiler would fail to detect have been brought to light by the hydraulic test combined with careful inspection." Apart from the fact that with many boilers pressure is the only means of ascertaining their strength and of detecting bad work, every boiler, no matter of what kind, should be submitted to the test either of steam or water. The former is in reality a bad practice; for, although it may be argued that it is placing the boiler under similar conditions to those of its future every-day life, it is more like an attempt to burst the boiler, and should never be tried till after the hydraulic test, when in fact it becomes unnecessary. As the hydraulic test is often applied, however, it shows nothing: the pressure must be maintained for a considerable time after all leakages have been remedied, and the measurements of the boiler while in this state compared with those taken before the pressure was put on. This plan at once indicates the amount of pressure the boiler has withstood, and the defects, if any; but to prevent any possibility of its being passed after having been strained beyond the limit of elasticity, a careful inspection is imperatively necessary. Many persons object to the hydraulic test on the ground that it does not indicate the actual strength after all, forgetting that it is not meant for perfectly sound boilers, but for the detection of weakness, and for proof that the boiler is capable of resisting the pressure at which it is to be worked multiplied by the factor of safety. It is obvious that to ascertain the actual strength of a boiler it would be necessary to burst it, or so strain it as to render it useless.

The chapter on boiler explosions is a repetition of what has been over and over again said; but Mr. Wilson enters into the various known and suggested causes, and of course points out that shortness of water is in many cases nothing more than an easy way of shifting responsibility on to the attendant, "who if not killed by the explosion, in many cases might just as well be, so far as his ability to defend himself is concerned." The combustion of coal, smoke prevention and firing, heating surfaces, and boiler power conclude the book, the last pages being occupied with tables of the collapsing and bursting pressures of tubes and shells. The volume is a concise treatise on the steam-boiler; it does not pretend to be a complete history, for the obvious reason that that would be impossible within the limits of its 328 pp. It nevertheless contains a large amount of information useful to steam-boiler owners and purchasers, and worth study by many of our boiler-makers.

IRON AND STEEL TIRES.

From "The Engineer."

A very serious accident, if the word may be so applied with propriety, occurred on Saturday last to an excursion train on the Midland Railway. The all-engrossing topic of the Shah's visit, and the fact that the train conveyed only railway servants—in whom, of course, it is not to be supposed that the general public can feel much interest—has led to the almost total silence of the daily press, with one exception, the "Standard," on the subject. The facts, so far as we can learn, appear to be as follows:—The Midland Company arranged that on Saturday last one of their regular annual trips for their servants engaged on the Derby and Leeds section of the Midland system should take place. The excursion trains run to various places, such as Manchester, London, Buxton, etc. The accident occurred to one of the trains proceeding from Leeds to Buxton. The train started about seven in the morning, and consisted of thirteen carriages. On nearing a bridge close to a place called Hallfieldgate, one of the leading tires of the engine broke, the engine then left the line and

ran down an embankment, taking with it one of the carriages. Two persons were killed on the spot and several others injured. Such are the facts within the smallest possible compass.

Pending the decision of the coroner's jury, it would of course be improper to pronounce an opinion as to whether any one was or was not to blame for the accident. But it can do no harm to say a few words here on the relative merits, as regards safety from breakage, of iron and steel tires. It would be folly to suppose that in the present day any locomotive engineer would return to the use of iron tires for driving wheels, and we have certainly no intention of recommending such a course; indeed, the weights now carried by first-class locomotive driving wheels are so great that driving tires would never be out of the lathe if made of iron. But we submit that the case is different as regards wheels not drivers, and especially the leading wheels of engines intended to travel at a high speed. A very considerable number of accidents of a serious type ensue directly from the breakage of engine tires. If this breakage is confined to the driving or trailing wheels, the engine may, and sometimes does, keep the line. It is a well recorded fact, for example, that some five-and-twenty years ago the driver of one of the up night trains on the London and North Western, or, as it was then called, the London and Birmingham Railway, ran for over 40 miles after he had lost the tire of one of his driving wheels, without being aware of what had occurred. He heard a crack, and felt the engine jump; but the night was very dark and wet, and he assumed that he had run over some obstruction and broken a life guard; so, as he found that nothing further occurred, he went on, and the broken tire was found next day at the side of the road 40 miles from London. When a leading tire goes, however, it is certain that the engine must leave the line. It appears, therefore, that more care should be taken to secure a perfectly reliable material for leading tires than is necessary for any other tires about an engine; and it is almost beyond question, we think, that a weldless Lowmoor or Bowling tire is in every respect more reliable than any steel tire that can be made. If the steel tire were perfectly sound and good, then unquestionably it would be better than a wrought iron tire in one sense. But the difficulty about steel tires is, that no one can assume with perfect certainty that a steel tire is quite sound and homogeneous all through. There are steel tires running now which we have little doubt are so brittle that no engineer in his senses would use them for an hour, if he was aware of their condition; but no one can be aware of their condition, consequently they are used, and also consequently, we may hear of a bad accident at any moment. That steel tires should be so uncertain is not the fault of the makers. It is an inherent defect in the material. It is all very well to take portions of a tire and assert that when pulled asunder they bore an enormous strain. The fact, standing by itself, proves nothing. In the first place, a tensile strain is but one of the many strains to which a railway tire is exposed when in use; and, in the second place there is no certainty that the metal in every portion of a steel tire is in all places alike, and equally tough and good. Opposed to all the theory in the world about steel, stands the notorious practical fact that the metal is uncertain in quality, and hard and brittle, as compared with the best qualities of wrought iron. After the most careful trials the use of steel plates in the construction of boilers is being abandoned on the Continent because of the uncertainty of the material. The rigidity of steel is at once the defect and the advantage of the material. Because steel tires are hard, stiff, and unyielding, they will not wear out quickly under heavy loads. But this very property of rigidity renders it difficult to shrink on a steel tire just tight enough, and yet not so tight that it will not be exposed to a heavy initial strain, certain to cause its ultimate destruction.

It is quite true that many accidents have occurred from the breakage of iron tires; but the breakage has nearly always occurred at a weld, and if the best class of Lowmoor or Bowling iron be rolled into a tire without a weld, then such a tire will be in all respects more trustworthy and less likely to break than any possible steel tire. It will be safer to set, and more reliable in every way, and for this reason we think it is well worth the attention of locomotive engineers to consider whether it would not be advisable in all cases where practicable, to use weldless iron tires instead of steel for locomotive engines.

In any case, if steel is to be used it should be so put on that the tire shall not leave the

wheel in case of fracture. Many arrangements for this purpose are well known to the world, and it is little short of criminal for any engineer to neglect to adopt any expedient which will promote the safety of the public, if he has once convinced himself that it will fulfil its intended purpose. Of course, the real difficulty lies in getting men to assure themselves on any point when they are disposed to have doubts.

ON THE PORTATIVE FORCE OF MAGNETS.*

From the "English Mechanic."

The author submitted two magnets on the system he had made known to the Academy—one of mean dimensions, weighing 6 kilogrammes, and carrying 80; the other, the most powerful he has constructed, carrying 500 kilogrammes with a weight ten times less. Before describing them, he explains the principles of construction :—

I. The supporting force of a magnet depends upon very many circumstances—first, the mass of the contact and its exactness. If it be small, the magnet reserves a portion of its magnetism, and the contact takes at its two extremities two poles of the same name as those it touches. When its mass increases, this magnetism seems diminished, and disappears altogether at the extremity. At this moment the portative force is at its greatest, as all the magnetism is employed in producing it.

In this way the author has seen a contact support 267 kilogrammes applied alone to a magnet, and 305 kilogrammes, when two plates of iron have been added to the faces, increasing the weight. Notwithstanding, it will not do to augment the weight indefinitely, for that will diminish the action. For to decompose the magnetism of soft iron, the magnet expends part of its power. It is, therefore, necessary suitably to regulate the mass of the contact. It is also necessary to regulate the surface of adherence of this contact with the magnet—if it increases, the force diminishes; if it decreases beyond a certain limit, it acts like too small a contact; all the magnetism of the bar is not concealed.†

II. When a plate of magnetized steel is added to a group already formed, it experiences a first kind of influence: two equal quantities of magnetism separate themselves; one is drawn over against the group, the other is driven to the exterior face of the added plate; in other words, the solenoids that terminated at the surface of this group prolong themselves across the new plate, and even to the new surface, as if the primitive magnetism transported itself to this surface, and this action adds nothing to the former state of the magnet. But the latter produces two other actions: it forces to the exterior the magnetism that the plate had, and, on the other hand, it determines in this a contrary magnetism, the greater as it is the more energetic. The difference of these two actions represents the gain the additional plate brings to the group. This gain, at first considerable, diminishes as the number of layers augments; it becomes nothing at last, and the normal magnet is reached. The magnetism is maximum, and equal at M; the carrying force attains the limit at f, and each plate preserves a quantity of magnetism $e=\frac{M}{n}$, which decreases proportionally to the number n of the elements, and is always inferior to the quantity E, which they had received by the magnetization.

III. This quantity f is only a lower limit of the portative force. The contact of the magnet having been fixed on a suitable support, suppose we place successively against it the plates of steel that would form the magnet after having separately magnetized them to saturation. The magnetism E of each of them will disappear in exciting in the contact an equal and contrary magnetism that neutralizes it; but this magnetism will only be concealed, not destroyed, and the number of plates being n, the whole will no longer be confined; it will be nE; the portative force will be increased proportionally to the number of plates; it will be F, always greater than f, and the difference F—f will increase with n.

The author now proceeds to state that the

* Translated and Abstracted for the "English Mechanic."
† Relative to Concealed Magnetism, see "English Mechanic," p. 616, No. 416, 14th March, 1873.

whole of the magnetism of each plate is concealed by the contact. That occurs for the first plates; but their number increasing, the contact ends by being insufficient; a certain quantity of magnetism is no longer concealed, but remains free; it increases progressively, the plates react on each other, losing from their polarity and arriving at a new limit. During this time F has increased slowly, then remains constant.

F is a higher limit of the portative force. We will measure it by the first separation from the contact. Once the contact separated, the plates recover the magnetism that it had concealed; they are again delivered to their mutual influence, as when placed on each other without the contact; then they demagnetize themselves, each retaking the charge $e = \frac{M}{n}$ the group preserves its quantity of magnetism M, and the portative force again becomes *f*.

IV. When, by the first separation, the portative force has been reduced from F to *f*, it varies no more, or very little, by subsequent separations. It is possible to carry it back anew to its maximum value F; it suffices to surround each limb of the magnet with a spiral of electric wires, to apply the contact near the polar surfaces and remagnetize the bundle. The author has already published the results he has obtained in this case under the title of *Electric Condensation**.

The author has, for example, constructed a magnet with 14 superposed horseshoes of 70 centimetres length, weighing 10 kilogrammes. Five were enough to attain the magnetic limit, the nine others were surplus. Also, when separated, they were found nearly demagnetized; the portative force *f* was equal to 300. When the group was remagnetized with its contact applied, the force became F; it was equal to 700 kilogrammes; more than doubled. With magnets going less beyond the normal limit, the difference between F and *f* is smaller, but always considerable.

V. But F is a transitory and useless force, as it disappears on first breaking contact. On the contrary, *f* is a permanent force and expresses the true, always disposable power of the magnet. We must seek to increase it, which can be done with armatures placed in a certain way.

In fact, let us fix the two armatures beside each other in the position they ought to occupy when the magnet will be mounted; then let us place against them, one by one, the plates of steel separately magnetized, as was done before with the contact. If these armatures touch each other they will act as the contact itself would act, that is, they would conceal all the magnetism of each plate. Separating them little by little, and more and more, they still act in the same way, but with decreasing energy. They conceal only a part of the magnetism. The rest goes to the exterior surfaces. The plates partially discharged can react upon each other; they lose from their primitive magnetism, but less than without the armatures, and so much the less as these shall be separated. If we then apply a contact, we have a portative force F, less than F_1 but greater than *f*.

VI. To justify these ideas the author mounted a magnet of 45 plates of steel so constructed that one piece could be adjusted after the other on two iron shoes fixed one beside the other with copper stays. They were then enveloped with two spirals of copper wire. Under the shoes, of which the mass was independent,, there were two iron armatures weighing 4 kgms. each; they could be applied or taken away, and brought near or distanced in a groove in which they were made to slide. After the magnetization with these armatures and the contact, we find F = 380 kgms. The contact having been broken and then restored, the force becomes F_1 = 260 kgms. Taking away the armatures reduced the magnetization to a minimum; when they were replaced without fresh magnetization, the first force of 260 kgms. was not recovered, but only 170 kgms. On remagnetization with the armatures replaced, but without contact, 260 kgms. were reproduced. The effect of the armature was thus to raise it from 170 to 260, the true and permanent force.

The following proof confirms the foregoing:—A small proof contact is suspended to a tray of a balance over a point of the polar surface taken towards its interior edge, and the force for breaking this small contact is measured by the ordinary method. After a preliminary magnetization, it was equal to 1,130 grammes.

The armatures were distanced 100 millemetres and then restored to their first position; but the 1,130 grs. were not recovered,

* "English Mechanic," p. 30, No. 418, 28th March, 1873.

only 1,075 grs. On removing the armatures and then replacing them the force was further reduced to 925 grs. It is thus seen that an armature increases the force of a magnet, but conditionally *that it be applied previous to the magnetization;* otherwise it weakens it.

VII. From these facts we may deduce the conditions for the construction of a magnet, the best that can be made with plates of steel and of a given length.

1. The contact should conceal the whole of the magnetism spread over the exterior surface of the magnet. For that, it should be of a sufficient mass.

2. Thus a mass being given, we must reduce the surface of adherence until we perceive the little free magnetism that the application of the contact leaves upon the magnet increase.

3. When the length and breadth of the plates are determined, their number should be sufficient to make a little of the magnetism appear upon the magnet when the contact is applied. It the number be less, the limit of permanent force is not attained; if it be passed, nothing more is secured.

4. The armatures should be strong, well-applied, and very near together; nevertheless their weight must not be excessive.

VIII. These conditions established, the author thus constructed his magnet:—Two armatures, each weighing 16 kgms., placed opposite each other, are solidly fixed with very strong copper stays; their breadth 11 centimetres, their polar surfaces, horizontal and directed towards the base, 12 centimetres, their transverse thickness, 20 mms.; they were well dressed, and received a cubic contact of soft iron, weighing 13 kgms. Proceeding from these surfaces, the armatures rise on receding from each other, thin off from this, and terminate with a sharp edge.

They are reunited towards the upper part by a plate of steel of 1.20 m., screwed on their exterior surface that curves freely round, following the form determined by its elasticity. All the other plates previously magnetized are placed in the interior of this, one after the other; left to themselves, they adhere to each other, whilst their extremities rest upon the armatures; as their number augments, the portative force increases as follows:—

n.	F	F_1	$F-F_1$
20	175kg.	154kg.	21
30	316	280	46
50	460	376	84
45	558	460	98
50	600	475	125
55	680	495	185

The portative force F, which is measured after the first breaking of contact, is always greater than F_1, which is the permanent force. The difference goes on increasing rapidly up to 40 or 45 plates. At this moment is perceived an observable quantity of free magnetism on the extremities of the magnet and of the current. From 40 to 55 the force goes on increasing, but F_1 remains nearly constant, reaching about the limit of 500 kgms., a limit that cannot be passed in the given conditions of armatures, contact, and steel. Stopping at 45 plates, the total weight is 46 kgms, and the magnet bears 16 times its weight; but the relative quality of the apparatus diminishes rapidly when the number of plates is increased from this, since its weight augments more rapidly than its power.

MANUFACTURE OF IRON WITH HOT COKE AND GAS.

From "The Mining Journal" (London).

In the present modes of using fuel used in the smelting of iron ore the waste of heat is enormous, and from the large quantity of iron made it is a matter of very great and increasing public import to find a remedy. At present the volatile combustible gases are by the heat in the lower part of the furnace driven off unburnt, or nearly so, and the nuisance of smoke is caused. Where the coal is coked these gases, which in reality constitute the most valuable part of the fuel, and a considerable portion of the fixed carbon of the coal, are altogether wasted in the coke oven or open kiln, generally at once, the coal being so treated immediately on being drawn out of the pit. This waste, taking the calorific value of the gas into account, is on the average fully one-half of the heating value of the coal, and a large proportion of the iron of the country is made by coke fuel. When the coke is being drawn it is cooled

with water, and thus the heat, which if made available would materially aid in the smelting of iron, is lost, and the water used in cooling is to some extent absorbed by the coke, and requires to be evaporated by heat in the iron furnace, requiring combustion of fuel to do so; and the re-heating of the coke before it can enter into combustion also requires the consumption of fuel.

By the present modes the liquid hydrocarbons obtainable from the coal are also lost. Thus the fuel cannot be used so as to obtain the advantage that will arise from the immense reducing or smelting power of the concentrated heat of the gaseous or volatile and liquid combustible portion of the coal, and the improvement in the quality of the iron from the ore being reduced or smelted at a higher temperature from the consequent more thorough separation of the earthy part of the ore or slag, and also the improvement of yield in the ore, as from the higher temperature the slag will not only be more thoroughly separated from the iron, but the iron will be more thoroughly separated from the slag. In puddling-furnaces the gas from the coal used contains a considerable portion of the sulphur generally contained in the coal, which passes off with the combustible gas to the iron being puddled, and a considerable portion of the solid part of the coal is necessarily used in the fires of the puddling-furnaces simply to sustain the fire. The combustible gases of the coal partly pass off imperfectly burnt, causing not only the nuisance of smoke but waste of carbon, and there is the expenditure of much heavy hot labor in firing.

Such being the views entertained concerning the existing processes of iron metallurgy by Mr. W. Mickle, of Tynemouth, he proposes to treat the coal by dry distillation in retorts similar to those at gasworks in use in towns, and to have the gasworks contiguous to the smelting furnace; the works having the usual plant of retorts, gas holders, etc. And he recommends that the gas should also be purified thoroughly, as in ordinary gasworks. To economize the heat, and to have the immense advantage of smelting the ore on a body of fuel thrown into the furnace hot or red-hot, or approximating to red-heat, he draws the coke from the retort at the red or white heat, or whatever it may be, into iron or other suitable tubs or carriages without having the coke made cold with water or without cooling it with water, and convey it to the smelting-furnace and discharge it into the furnace as fuel, as the fuel is ordinarily charged, or if requisite from the heat, by engine power. With this he combines the use of the coal gas, and also the naphtha or other combustible oil or spirit obtained from the coal used for smelting, the gas being simply pumped from the gasholder by engine power through pipes and tuyeres to and into the furnace (in a similar way to the air pumped from the blowing-engine). If the said liquid hydrocarbons be used in the smelting-furnace, they could be similarly pumped from a tank or receiver. He recommends that the gas be well purified, and also that valves opening to the furnace be fixed or joined into the pipes near the furnace, so as to prevent any return air getting mixed with gas in the pipes, and causing an explosive mixture. The gas not used in the smelting-furnace can be appropriated to the usual lighting and heating purposes, and the liquid hydrocarbons can be used for general purposes.

In puddling iron he distils the coal in the same manner, and pumps the coal gas as fuel from the gas-holder through pipes, and also the air required for combustion through pipes from ordinary blowing apparatus similarly to that for smelting into the puddling-furnace to puddle the metal. He recommends the gas to be thoroughly purified, and the air and gas pipes, etc., to be conveniently small and numerous, and well mixed together, so that the air and gas may be well mingled for the purpose of obtaining thorough combustion. Or the air may be supplied as at present, but he recommends it to be pumped through pipes. The gas coke can be used for smelting or any other useful purpose. This mode will prevent or greatly diminish the labor of stoking or firing, and the impurity from the coal and the smoke, and also the waste before named. The heating of the air-blast will not, he thinks, with the use of the coke put into the smelting-furnace hot or red-hot, and the coal gas pumped in as above, be found needful, as the heat will, independently of the air being heated, be so great that the heating of the air may be dispensed with. The air might be heated at option, and where esteemed convenient by the air-blast pipes being passed along or round the retort furnaces or flues or chimneys, in such a manner as to get the benefit

of the waste heat from them. The coal gas will for pumping require to be cleared of the tar, and should be well purified; but after allowing for what condensation these require, it will save heat by pumping it into the furnace as nearly to the temperature the gas leaves the retort as may be, and the gas-holder and the pipes from the retort could, if thought desirable, be covered with felt or other covering.

The retorts may at option be heated with the smelting-furnace waste gases, or the carbonic oxide, hydrogen, etc., and heat of such waste gases. The retorts may also be so heated with the puddling-furnace waste gases. The gas engine boiler fires if the air-blast engines be not used for pumping the gas as to smelting, or if pumps be not attached to other engines at the puddling-works, can also be so heated. The coal gas is pumped into the smelting-furnace in close proximity to the air, so as to be most powerful gas blow-pipes, and to obtain a most intense concentrated heat in the hearth or crucible. And he believes that from the use of coke put into the smelting-furnace hot, and the use of the gas as before named, the increment of heat in the furnace will be very great, and that consequently on this the flow of metal will be rapid, and the produce from the furnace much increased. The calcining of ore will not, he thinks, with the charging of hot coke into the smelting-furnace, be found requisite.

After allowing for the fuel required for the deoxidation of the ore, and the carbon of the fuel necessary for the carburization of the metal, he believes that with the intense concentrated heat from the gas blow-pipes, and the use of coke put in hot, much weight of fuel may not be needed, and that, therefore, the enormous weight of air at present used for combustion will be greatly diminished, and a great saving of the engine power and blowing apparatus for pumping the air, and the fuel and labor used for such engines, will be effected. Although it may be found advantageous to have large furnaces, yet from the use of a mass of coke thrown into the furnace hot the produce of metal from the furnace will be so large that in future the iron smelting-furnaces need not be, he thinks, erected so large and costly as at present; smaller and cheaper ones yielding metal in large quantities.

The intensity and increment of heat by this process will more highly liquefy the metal and slag in the iron smelting-furnace, thus more thoroughly separate the metal and slag, and as a result the iron will be purer and better in quality, and more yield from the ore than at present. He believes that with this process a great deal of small and inferior gas and coking coal, hitherto found unsuitable for iron smelting, will be rendered available for smelting. Supposing that there be used in the iron smelting-furnace to make a ton of metal 25 cwt. of coke, and 5 cwt. of this coke be absorbed or required in deoxidizing the ore and carburizing the metal, there will be 20 cwt. of coke for combustion with the air pumped in, and about 8 tons, or about 240,000 cubic ft. of air pumped into the furnace for combustion with the coke, about three-fourth parts, or 6 tons of such air will be nitrogen, which is not only non-combustible but requires heat, and consequently the consumption of fuel in the heating stoves, if hot air be used, and in the blast-furnace to heat it to the temperature in the furnace or the hearth of the furnace; thus about 6 tons or about one-half of the whole of the materials put into the furnace being not only useless (excepting perhaps as to cyanogen) but detracting from the heat of the furnace and requiring fuel to raise its temperature. The use of coke put into the furnace hot, which heat assists in the smelting of the metal, diminishes the air, and consequently the nitrogen required, and lessens the detraction from the heat in the hearth caused by the nitrogen.

Mr. Mickle is of opinion that on smelters becoming familiar or thoroughly conversant with his process, the use of coke put in hot, and coal gas, will from the intense heat give so much and so potent a command over the reduction or smelting of the ore, that 8 to 10 cwt. of the gas produced and heated coke may be found sufficient in the furnace for fuel, inclusive of what is required for deoxidation of ore and carburization of metal; if so, it will only require about one-fourth of the air, or about 2 tons, thus diminishing the available air-blast power required three-fourths; and, as before named, he believes that previous calcining and heating stoves may not continue to be used, and the engine boilers and retorts may be heated with the furnace waste gases; the general result would be that the metal may be smelted with the total consumption of about ½ ton of coal. And supposing that

on the average there be now used to make a ton of metal for calcining, engine power for pumping the air, heating the air, and smelting the ore, about 3½ tons of coal, the net saving would be about 3 tons of coal in making 1 ton of metal, and as there are now making in this country nearly or about 7,000,000 tons of pig-iron annually, the saving at the present rate of make would be nearly 20,000,000 tons of coal annually, which is a matter of very great and increasing importance. He does not bind himself to the extent of saving mentioned, but thoroughly believes it will be so, that is, the reduction of consumption of fuel to about 10 cwt., or the general saving of 20,000,000 tons of coal on the present make of pig-iron annually, more or less, or approximating to it.

It is claimed that the process will enable iron to be produced much cheaper, and thus stimulate the building of iron ships, railways, etc., and generally foster the staple industries of the country, as well as free a large quantity of coal for domestic use, which is much needed, and which would be a great boon to the poor and to the public generally. When convenient it will be desirable for the puddling-furnaces to be near the smelting furnaces, so that the heated coke made in distilling coal for the gas for puddling may be used in the smelting furnace, and thus save the heat of the heated coke; and also that the air-blowing apparatus attached to the smelting-furnaces may be available for pumping air to supply the combustion at the puddling furnaces. When the coal gas is well purified he believes it to be a very pure or fine and superior description of fuel, and will aid in making higher class iron, whilst coal gas purified as ordinarily, and used as before named for puddling, will tend to make better malleable iron, and that both as regards smelting and puddling there will be much more command over the heat of the furnace, as the force of gas and air and consequent instantaneous heat can be increased when desirable by accelerating the motion of the engine and pumping. Where there are beds of iron ore at a distance from coal, as for instance those in the oolites and lias, he considers that this process as to the fuel will be of great value in developing them, and may be of essential import where the ore is at present considered too poor to smelt, because he believes that the quantity of fuel required will be relatively small, and, therefore, the cost of carriage low, and the power of heat great over inferior ores. In using peat, wood, or other fuel which yields on distillation solid and gaseous combustible products economically, and in sufficient quantity for iron smelting and puddling, he subjects it to dry distillation, and then treats and uses the combustible products.

WHITTBREAD'S SEWAGE PROCESS.

From "Engineering."

In several preceding articles we have described a variety of schemes that have been proposed to treat sewage by chemical means, including the A B C, the Phosphate, Dr. Anderson's, and others. All these have been put on their trial, and have in numerous respects been found wanting. If anything in the form of a valuable manure has been obtained, the resulting effluent has suffered; if, on the other hand, the effluent, or purified sewage, has been tolerably good, then the manure has been of little value. There have been, therefore, a Charybdis and a Scylla to avoid; and some of these schemes have, therefore, been run on the rock of failure, despite the careful generalship of their advocates. Whittbread's process promises to move some errors of those which have preceded it. The following affords an account of its chief characteristics, for which we do not hold ourselves responsible.

In a general description of this process the patentee states that its object is to remove the inorganic impurities of the sewage treated by chemical precipitation, and he describes the results as producing a really valuable manure; while the effluent water is clean and inoffensive, sufficient to satisfy the demands of any reasonable river Conservancy. Following the expression of this opinion, it is stated that no other chemical process of treating sewage has resulted in precipitating a really valuable manure, giving for that opinion a supposed fact, that no process has been efficacious in precipitating the putrescible organic matter; and that no process has resolved the

organic nitrogen in solution, which the patentee claims to have accomplished.

The agents which he employs for such treatment of sewage are entirely recovered, besides from 50 to 70 per cent. of a more valuable manure, in the form of a mixed mass. For this purpose he uses a solution of dicalcic phosphate (a phosphate of lime) in a water solution of monocalcic phosphate (or superphosphate of lime). A small quantity of lime (we suppose either caustic or slaked) is added in order to precipitate a dicalcic phosphate, which is stated to afford a chemical fact hitherto unknown, that of a combination of such salt with the organic nitrogen in solution in the sewage. The patentee claims that, although the process, at first sight, may be expensive, it recovers nearly double the weight of the chemicals employed, and in a still more valuable form. It is stated that the materials employed can be cheaply produced. It would seem that the early experiments have been made by calcic phosphates or superphosphates of lime obtained from the ordinary chemical manufacturers of the latter manure, but the patentee considers that from natural deposits of the phosphates of lime, and from other sources, he may obtain these materials at much less cost than the first experiments incurred.

Such is a brief resumé of what may be termed the basis of this "dicalcic phosphate process." Any one with the slightest knowledge of chemistry will perceive that it is merely a modification of the Phosphate Sewage Company's process, in which is employed a natural phosphate of alumina, which is subsequently treated with sulphuric acid, to set free a certain portion of phosphoric acid, to combine with the lime added at a certain stage of the process. Here we must repeat, what we have before so frequently stated, that if all the patentees for the chemical treatment of sewage were arranged before a competent tribunal, we should have one of the most interesting trials at law that could possibly be imagined. The chief sufferers would be, ammonia and phosphoric acid, in regard to chemical science; the other would be the reputation of those chemists who took part in the evidence; and the last, the poor shareholder of the advocating companies, who have all tried, by the investment of capital, to prove that truth or science is false, and that the laws imprinted on nature are as tortuous as the flexibility of man's interest demands. To put the matter, indeed, in a common-sense point of view, the patentees of most of the chemical sewage schemes have undertaken to invert, in the majority of cases, the well-ascertained laws of natural and chemical philosophy to prove the truth of their individual schemes.

But the position of Whittbread's process is fortified by the following statement, which has been placed in our hands, as the result of experiments, and the reports of certain officials. We copy that statement nearly *verbatim*. The Liverpool sewage was treated in the presence of Dr. French, the medical officer of the borough, and Dr. Campbell Brown, the borough analyst; the experiment was tried on two tons and a half of sewage. The precipitate contained 39 per cent. of phosphate of lime and 4.75 per cent. of ammonia. This manure would, therefore, have been worth £6 to £8 per ton (a rather wide margin). There was upwards of 50 per cent. more weight of dried manure than of chemicals employed; thus one ton of chemicals, costing £4 10s., would produce 1½ tons of manure, worth £9 to £12. In another experiment, 1 ton 17 cwt. of manure was obtained by the use of one ton of chemicals. The manure contained 28 per cent. of phosphate of lime and 3.8 per cent. of ammonia. Giving an estimated chemical value of £5 8s. to £6 16s. per ton. It is stated that the effluent water in both cases was almost entirely free from putrescible organic matter, and inoffensive.

The following results were reported by Dr. Corfield on a large experiment carried on at the sewage farm at Romford, Essex. He stated before the British Association that Whittbread's process had been examined by the Sewage Committee on a sufficiently large scale to test its merits. The process consisted of adding to the sewage a mixture of two equivalents of dicalcic phosphate, with one equivalent of monocalcic phosphate, the latter being added in the form of commercial superphosphate. Milk of lime was afterwards added. The resulting precipitate was very rapid, and the supernatant water clear and inoffensive. The general result was that the suspended matter was removed, and that the organic matter was also nearly eliminated. The ammonia in the sewage was slightly increased, and a certain quantity of phosphoric acid remained in solution in the effluent water. The committee of the British Association

very wisely considered that a single experiment was by no means conclusive. The most important results obtained was the precipitation of a large amount of phosphate of lime, and in the case of this experiment, the retention of 3 per cent. of ammonia in the resultant manure. An analysis, by Dr. Russel, of the process, showed the following results. In the original sewage there was nitrogen in the organic matter equal to 6.204, which was reduced in the effluent to 0.17. The precipitate contained 17.87 per cent. of phosphate of lime; phosphate of iron and alumina 5.94; and ammonia about 3 per cent., giving a value of about £6 per ton. In an experiment at Buckhurst Hill on 84,375 gallons of sewage it was found that in 100,000 parts of raw sewage there were 62.50 parts of organic matter. The effluent water contained but 10 grains, hence showing a removal of 52½ grains. The actual quantity gained in the manure was 42½ grains. The total amount of chemicals used was about 84 lbs., and the result was the production of 3 cwt. of drained mud, affording 128 lbs. of dried manure. In the effluent there was no trace of albumenoid ammonia; the amount of ammonia in the manure was 3 per cent., giving a value of about £5 per ton. There was no odor perceptible during the operation, nor offensive smell given off during the drying process. The precipitate was thrown down in a flocculent form, and not in a kind of gelatinous condit on, as afforded by other processes. It appears that the precipitate is easily dried, either by exposure to the atmosphere, or by artificial heat.

The preceding description would seem to show that at least one really practicable means of dealing with sewage by chemical treatment has been discovered; but, in the words of Virgil, we fear the Greeks, even when giving gifts. The promises held out by this process are excellent, but our past experience leads us to hesitate in accepting them. The analogies of physiology, so far as the formation of bone in animals, seem to lead to the hope that this so-called "dicalcic phosphate" process may have at least a theoretical prospect of success, but at present the commercial result has to be tested on a much larger scale than has hitherto been attempted, and until that is effected its value can only be a matter of pure guess-work. We trust that the patentee will make such a trial as will not be simply affirmative of the statements already issued in favor of the process, but also as affording sufficient data on which to found a really reliable chance of proving its general applicability to sewage of all kinds. Rich or poor sewage may be treated with such opposite results, both chemical and commercial, that at present the solution of the sewage question remains open.

SOME EXPERIMENTS UPON THE TRANSVERSE STRENGTH OF SOLID CYLINDERS OF WROUGHT IRON.

By J. LEE MARSH.

Written for Van Nostrand's Magazine.

Having occasion, in designing a railway bridge, to determine a coefficient for the safe centre load of horizontal solid cylinders of wrought iron, I consulted Mr. John C. Trautwine's "Civil Engineer's Pocket Book."

The coefficient for the quiescent breaking loads of rectangular beams of wrought iron, supported horizontally at both ends and loaded at the centre, is given by Mr. Trautwine as 2,400 lbs. average; the elasticity, he adds, is injured at about $\frac{4}{10}$ of the above load. The strength of a cylindrical bar, with diameter equal to the side of a square bar, is given as .589 of the latter.

With these figures I found that my safe centre load for a cylindrical bar 2 in. in diameter and 2 ft. between supports, was but 3,840 lbs. Thinking this result not quite satisfactory, I proceeded to test the behavior of cylindrical bars under the above-named conditions.

In my experiments the stress was weighed upon a Fairbanks' platform scale, the load used being pig iron applied at the end of a lever. In applying and removing the load considerable vibration was produced; probably not less than the bar would be subjected to in a railway bridge.

The result of my experiments, given below, may be of interest to others engaged in pursuits similar to my own.

FIRST EXPERIMENT.

Elmira Rolling Mill Company's merchant bar (rough, but straightened by planing slightly on the bottom side), $1\frac{3}{4}$ in. diameter and 2 ft. between supports, loaded at the centre with load of

500 lbs.	deflected	.03 inches.
1000 lbs.	"	.06 "
1500 lbs.	"	.09 "

On removing the load, no set was found to have taken place; 2,000 lbs. was then applied and left on the bar for the space of an hour, the bar deflecting .125 in. On removing the load the bar retained a set of .005 in.; 2,500 lbs. were then applied, with a deflection of .5 in and a set of .37 in.

SECOND EXPERIMENT.

Elmira Rolling Mill Company's merchant bar (treated as above), 2 in. diameter, 2 ft. between supports, and loaded at the centre with load of

500 lbs.	deflected	.01 inches.
1000 lbs.	"	.02 "
1500 lbs.	"	.03 "
2000 lbs.	"	.04 "
2500 lbs.	"	.05 "
3000 lbs.	"	.06 "
3500 lbs.	deflected.	.07 inches.
4000 lbs.	"	.08 "
4500 lbs.	"	.09 "
5000 lbs.	"	.1 "

At this point the load was removed, but no set was visible. A load of 5,500 lbs. was then applied, the deflection being .11 in., but with 6,000 lbs., the deflection increased to. 125 in., showing the elastic limit to have been passed. On removing the load the set was found to be .0075 in. The bar was again loaded with 6,500 lbs., deflecting .16 in., and with 7,000 lbs. the deflection reached .23 in., leaving a set of .11 in.

I assume that in these experiments the loads representing the elastic limits of the bars tested are for the first 1,750 lbs., and for the second 5,500 lbs.

Then in the formula

$$\text{load} = \frac{\text{area} \times \text{depth} \times \text{coefficient}}{\text{length between supports}},$$

the coefficient of strength, within the limits of elasticity, for solid cylindrical bars of wrought iron supported horizontally at both ends and loaded at the centre, is 1,760 nearly.

HYDRODYNAMIC FORMULÆ.

From "Engineering."

Those that conscientiously wish to choose and employ in practice a formula that will, from given hydraulic data of a river, canal, sewer or pipe, give its true mean velocity of discharge, and hence the actual discharge accurately, have a difficult task before them. The science of hydrodynamics being yet little more than experimental, the conscientious investigator has to study the works of a vast number of writers on this subject, a large proportion of which are foreign. Again, should the engineer prefer making personal inquiries among his engineering friends as to the practice usually adopted to obtain rapidly and conveniently a result, which at the outset might appear very simple, he discovers that some of his friends adhere invariably to the tables and formulæ of one author, and some to others. An examination of these tables, and the formulæ on which they are based, shows them to differ to an extraordinary degree. What then remains to be done before choosing and adopting a formula for ordinary use? Evidently a careful tabulation of the results of various formulæ in comparison with actually measured discharges.

To begin then with rivers:

In two smaller cases the comparisons were made by Mr. David Stevenson, and are recorded by him.

1. For a small stream of 24 cubic ft. per second. Mr. David Stevenson made careful measurements, and velocity observations, and compared the measured results with the results of formulæ, thus:

1. Measured discharge	24.22
2. By formula of Dubuat	32.59
3. By Robison's formula	36.90
4. By Ellet's formula	46.40
5. By Beardmore's Tables	38.92
6. By Downing's formula, coefficient 1.00	41.23
7. By Leslie's formula, coefficient .68	28.04

2. For a river of 2,424 cubic ft. per second. Mr. David Stevenson and Dr. Anderson made velocity observations on the Tay, at Perth, and the comparisons are thus:

1. Measured discharge	2423
2. By formula of Dubuat	2987

3. By Robison's formula	2560
4. By Ellet's formula	2033
5. By Beardmore's tabular formula	2699
6 By Downing's formula, coefficient 1.00	2769
7. By Leslie's formula, coefficient .68	2083

It is unfortunate that in these two cases the hydraulic data, which would enable us to extend the comparison to other formulæ, are not given.

3. For a large river of 31,864 cubic ft. per second. The Great Nevka had its data measured by Mr. Destrem, as follows:

Area of section	15,554	width	881
Discharge	31.864	perimeter	893
Mean velocity	2 0486	maximum depth	21
Slope	.00001487		

The following are results due to these data calculated by various formulæ for mean velocity of discharge:

1. Measured discharge	31,864
2. Young's coefficient	21,102
3. Eytelwein's coefficient	23,389
4. Downing's coefficient	25,031
5. Dubuat's formula	16,931
6. Girard's formula	22,491
7. De Prony's canal formula	22.357
8. Young's formula	19,777
9. Dupuit's formula	23,546
10 St Venant's formula	21,811
11. Ellet's formula	13,807
12. Mississippi new formula	32,938

4. For a very large river, the Mississippi at Carrolton, the measured data at high water in 1851 were:

Area of section	193,968	width	2653
Discharge	1,149,998	perimeter	2693
Mean velocity	5.9288	maximum depth	136
Slope	.00002051,		

and the corresponding results which are kept in terms of mean velocity to reduce figures:

1. Measured	5.9288
2. Young's coefficient	3.2400
3. Eytelwein's coefficient	3.5898
4 Downing's coefficient	3.8434
5. Dubuat's formula	2.7468
6. Girard's formula	4.8148
7. De Prony's canal formula	3.7271
8. Young's formula	3.2741
9 Dupuit's formula	4.8752
10. St. Venant's formula	3·4907
11. Ellet's formula	3.0451
12. Mississippi new formula	5.8903

A careful examination of these results in four cases of rivers cannot fail to be instructive; but before entering into comment on the discrepancies and their peculiarities, let us also examine the following list of total discrepancies of mean velocity in thirty cases of rivers, streams and canals of all sizes, given by Captain Humphreys and Abbot in the Mississippi Report. They would, no doubt, be more instructive were the cases classified as to size, but even massed up as they are, the comparisons are still instructive.

The total discrepancies are:

1 Measured mean velocity of discharge discrepancy	0.
2. Young's coefficient	32.9420
3. Eytelwein's coefficient	28.4411
4. Downing's coefficient	26.6988
5. Dubuat's formula	40.4417
6. Girard's formula	37.4472
7. De Prony's canal formula	28.0965
8. Young's formula	35.3834
9. Dupuit's formula	25.1488
10. St. Venant's formula	30.6619
11. Ellet's formula	45.3547
12. Mississippi new formula	6 39:0

From this last table of discrepancies it appears that the Mississippi new formula is by far the most correct, and after it the formulæ of Dupuit and Downing, while the two worst are the formulæ of Ellet and Dubuat; but then it must be remembered that the greater number of the thirty cases are those of large and very large rivers.

In the fourth of the previous cases, a very large river, the Mississippi new formula is by far the most correct, and then come in order of correctness, Dupuit, Girard and Downing, while Ellet and Dubuat are again the worst. In the third case Downing is most correct, then Dupuit, afterwards the Mississippi new formula, Ellet and Dubuat again the worst. In the second case Ellet and Dubuat remain the worst, and the best are Robison, Beardmore, and Downing. In the first case Leslie and Dubuat are best, and Downing worst.

It will be understood that the formula mentioned as Downing's, being more familiar to many under that name, is really that of D'Aubuisson, but applied to English measures.

The inevitable conclusion from all these comparisons is that no one formula is correctly applicable to rivers of different sizes, nor holds its own equally as regards correctness throughout. For the few and special cases in which the discharge of an extremely large river is required, the Mississippi new formula would necessarily be used, in spite of its form being rather unwieldy; and in the same way Dupuit's formula for a large river. But for ordinary general purposes the thing that the practical hydraulic engineer requires is a formula tolerably well suited to all cases and of a simple form, so as to admit of easy rapid calculation. The most simple type of for-

mula is that of Downing or D'Aubuisson, which gives for mean velocity of discharge

$$V = 100\,(R\,S)^{\frac{1}{2}}$$

where R = mean hydraulic radius
and S = mean hydraulic slope

and this, too, is the formula shown to have been generally the most correct throughout all the comparisons and discrepancies, failing only in the very smallest streams, and evidently worse according as the stream or discharge is less; this, then, is evidently the best formula for general purposes, and simply requires modification by experimental coefficients to answer all ordinary requirements.

The formulæ of Young, Neville Eytelwein, Beardmore, Stevenson, and Leslie, all belong to this type, merely using other numerical coefficients instead of 100.

Putting Downing's formula into the general form

$$V = c \times 100\,(R\,S)^{\frac{1}{2}}$$

where $c = 1$ according to Downing,

the values of c, according to the other formulæ of the same type, are thus:

	$c=$
Young, for large streams	.843
Neville, rivers, velocity < 1.5 ft	.923
" " " > 1.5 ft	.9 3
Eytelwein, generally	934
Beardmore, open channels	.942
Stevenson, for rivers of 30 cubic feet	.690
" " 2500 cubic feet	.960
Leslie, small streams	.680
" large streams	1.
Downing, Taylor, D'Aubuisson — for open channels	1.

From the comparison of the results of the formulæ containing these coefficients we are then able to tabulate values of c that will be practically correct; and when suitably applied to the general formula cannot fail to answer all ordinary purposes.

The comparisons before mentioned show that Downing's coefficient 1.00 gives too small results in cases when the area exceeds 7,000 sq. ft., with a mean velocity of 2.5 ft., or a discharge of 17,500 cubic ft. per second, and too large results for cases of smaller data; that the Eytelwein coefficient .934 in the same way is too small above and too large below discharges of about 2,000 cubic ft. per second; and the Young coefficient .843 is incorrect for every thing above 900 cubic ft. per second; also that for petty streams of 25 cubic ft. per second, a coefficient of about .600 is tolerably correct.

It is evident, then, that with a very large number of cases of carefully measured discharge, this principle of determining practical coefficients in relation to approximate volume or velocity might be carried out to further exactness, and it is very desirable that this should be done.

In the mean time, however, by making use of such cases as we happen to have, the suitable values of the practical coefficient c will be as follows:

By volume for regular channels in good order,

	$c=$
Large rivers of 17,000 cubic feet per second	1.00
Ordinary rivers of 2,500 " " "	.95
" " 2,000 " " "	.93
Small rivers, 1,000 cubic feet per second	.85
Small streams, 100 " "	.75

By velocity for regular channels in good order,

	$c=$
Rivers, velocity exceeding 3 ft. per second	1.00
" " " 1.5 ft. "	.94
" " " .25 ft. "	72
Canals, cuts, culverts of good masonry	1.00
" earthen, in good order	.92
" after wear	.90

By the application of coefficients on this principle we may then obtain in any case results not more than 2 or 3 per cent. from absolute exactitude, a great advantage and improvement on the very large errors that would be made by adhering either to any of the tables or formulæ yet known.

Allowance for irregularities, lateral bends, and so forth, can be made independently of this coefficient, as would be done in any case.

To apply this same principle to discharges through pipes, taking the same general formula,

$$V = c \times 100\,(R.\,S.)^{\frac{1}{2}}$$

As this formula becomes more convenient in practice in terms of the diameter of the pipe (d) it becomes, for full cylindrical pipes and tubes, where $R = \frac{d}{4}$

$$V = c \times 50\,(d\,S)^{\frac{1}{2}}.$$

And again as the actual discharge is the quantity most often wanted, this is

$$Q = A\,v = c \times .7854\,d^2 \times 50\,(S\,d)^{\frac{1}{2}}$$
$$= c \times 39.27\,(S\,d^5)^{\frac{1}{2}}$$

and transposing this to obtain diameters

$$d = .23\left(\frac{Q^2}{S}\right)^{\frac{1}{5}}.$$

Taking, then, an example to obtain comparisons with the discharges obtained by

calculation with the formulæ of other well-known authors.

Let Q = 18.57 cubic feet per second
S = 1 in 12.6,

and the results are for diameter:

1. By Dubuat's formula	33.74
2. By Neville, coefficient .228	36.80
3. By the above formula, coefficient 3.2	37.12
4. Young's modification of Eytelwein	37.17
5. Beardmore, coefficient .235	37 92
6. Hawksley (in Box's tables)	39.59
7. De Prony and Darcy	47 71
8 De Prony's modification of Dubuat	48.16
9. Gerney	48.84

Besides these there are very many authors that would give results for diameter very much below that of Young, and many of them are complicated and inconvenient. It appears that none of these formulæ apply equally well to both high and low velocities of discharge, although it is unfortunate that a sufficiently large number of data are not forthcoming to determine correctly the limits at which it would be advisable to change the coefficient.

The formula given, viz.:

$$d = .23\left(\frac{Q^2}{S}\right)^{\frac{1}{5}}$$

or,

$$v = c \times 100\,(\mathrm{R\,S})^{\frac{1}{2}}$$

seems to hold its mean of correctness about as well as any of the other formulæ, and perhaps for the present it will be as well to adhere to it, as in the case of rivers and canals; to modify it the following few values of practical coefficients, or values of c, may be useful.

	$c=$		
Pipes with very high velocities	1.10	....	.221
" high velocities	1·00	....	.230
" velocities 1.5 ft. per second.	.96	....	.234
" " 1.0 "	.95	....	.245
" lower velocities	.93	....	.236

The latter coefficients are for the transposed equation for obtaining diameters.

It is, perhaps, hardly necessary to remark that for old or rusty pipes, or for any abnormal state of the interior of pipes, further modification would be requisite in order to determine discharges accurately; but this would be necessary whatever formula might be adopted.

The absolute necessity of adhering to some such principle as the foregoing for obtaining discharges even approximately correct, has been shown by the foregoing data, and the type adopted has the advantage of extreme simplicity. Tables giving the values of the general formula adopted are given by one or two authors, and the judicious application of the suitable coefficient is then all that is required in practice. This investigation will, it is hoped, save labor to those entering newly into the subject, and, besides, point out to others that are more experienced, the extreme fallacy of adhering to any one author, or set of tables or formulæ, whether Neville, Beardmore, or Box, as well as provide them with a convenient substitute that insures practical accuracy of result.

ON SUBSTITUTES FOR COAL IN THE PRODUCTION OF ILLUMINATING GAS.*

By HENRY GORE.

From "The Journal of Gas Lighting, Water Supply, and Sanitary Improvement."

The recent extraordinary advance in the prices of coals used in the manufacture of gas has induced several persons to turn their attention to the possibility of employing other substances than coal for the production of illuminating gas, and within the last 12 or 18 months a number of suggestions have been made, and not a few patents taken out for inventions, each of which claims to have discovered the means by which the desired end may be arrived at. The author of this paper proposes to lay before the members of the association a brief history of what has been accomplished up to the present time in endeavoring to produce illuminating gas from other substances than coal, pointing out in passing what he believes to be the comparative value of the several processes, and also endeavor to give some reasons why such processes have not come into general use.

Before, however, proceeding to describe the various contrivances that have been from time to time brought forward to supersede the use of coal in the production of artificial light, the author would beg to call attention to some conditions which are

* A paper read before the British Association of Gas Managers.

essential in estimating the value of any substance that is proposed to be employed to furnish light. These conditions may be broadly stated as follows:—

1. That by combustion of the body a sufficient degree of heat be evolved to maintain continuous combustion.

2. That, when the burning body is a solid, it can be easily converted into vapor previous to its complete combustion, as otherwise no flame is generated which is absolutely required for the purpose of illumination.

3. That the burning body evolve in the flame solid matter or very dense vapors, as an essential condition of the illuminating property of the flame.

4. That either the body itself or the raw material from which it is obtainable be present in large quantity and readily accessible.

5. That the products of combustion be gaseous and harmless to the health.

It is a generally known fact that any great accumulation of heat imparts to bodies the property of emitting light. This is more conspicuous in solid and fluid bodies, because their molecules are placed more closely together than is the case in gases and vapors; thus, at a temperature of 1,000 deg. Fahr. a solid body becomes red hot, at a little over 1,800 deg. white heat or perfect incandescence occurs; but a gaseous body heated to these degrees of temperature would only emit a very feeble light. In order to render a gaseous body luminous during its combustion, it should contain the vapors of some of the higher class of hydrocarbons, and that these, becoming white hot, should yield light. A combustible gas may be used to ignite solid matter accidentally placed within its flame, and thus produce light, as in the case of a coil of platinum wire exposed to the flame of hydrogen gas, or a cylinder of lime or magnesium in the oxy-hydrogen flame; but, as these lights can only be employed under very special circumstances, it is not necessary to include them in the consideration of the present subject. It is clear that for all practical purposes we can only avail ourselves of such materials for illumination as yield a flame which emits light in consequence of the vapors of heavy hydrocarbons present therein. These hydrocarbons are, indeed, contained in all the substances which are either used for illuminating purposes, or from which illuminating materials are prepared; as, for instance, tallow, palm oil, stearine, wax, spermaceti, paraffine, vegetable and animal oils and fats, mineral and essential oils, coals, shales, or bituminous schists, wood, and resins.

The recent investigations into the character and composition of luminous flames made by Helgard, Kersten, Delville, and Frankland, have led to a considerable modification of the views previously held by chemists as to the precise form which the solid material assumes when undergoing complete combustion. Recent observations would lead to the supposition that the particles of carbon are not separated in a solid form as had been previously supposed, but that they are consumed in the shape of very dense vapors at the extreme outer envelope of the flame. This view seems to account for some of the phenomena which are observable when hydrocarbon vapor is burnt under the form of air gas, and has no doubt favored the use of the more volatile vapors derived from the distillation of petroleum oils.

It would be impossible, within the limits of this paper, to make more than this passing reference to the recent researches relative to luminous flames, but the information to be derived from these researches is unquestionably of very great importance when applied in connection with certain processes which have recently attracted so much attention—the "air gas" and the "new gas."

The substances from which artificial light has hitherto been derived may be divided into three distinct classes:—

1. Those bodies which are solid at ordinary temperatures, such as tallow, stearine, wax, paraffine, and spermaceti.

2. Fluid substances capable of burning in lamps, such as animal and vegetable oils, camphene or other form of essential oil, and the several varieties of mineral oils, or petroleum.

3. Gaseous substances, derived directly from the destructive distillation of coals, bituminous schists, peat, wood, resin, animal and vegetable oils, fats, and crude mineral oils; or by secondary processes, such as the so-called water gas obtained by passing steam over red-hot metal or charcoal, and then bringing the resultant gases in contact with substances rich in hydrocarbons; or, in another way, by passing currents of more or less dry atmospheric air over the surfaces of highly volatile hydrocarbon com-

pounds, as in the case of the various forms of air gas.

The chemical constitution of illuminating gas may be stated to consist of three primary sets of compounds. We discard for the present purpose the impurities that are present in greater or less quantities in all gases derived from destructive distillation. First we have the luminous gases, next we have the hydrocarbon vapors, and then we have the diluents, or, as the German chemists very appropriately call them, the light-bearers. The substances, therefore, best adapted for the production of illuminating gas are unquestionably those in which the elements just mentioned exist in the proper proportion, and hence the value of cannel coal as a gas-producing material. Next to cannel coal come the several varieties of bituminous coal, and of substances other than coal. The oils, fats, and resins rank first, as being best suited for the generation of gas by destructive distillation; then we may take wood, peat, and vegetable refuse as substances capable of producing gas, but of inferior value, from the deficiency of luminous gas or hydrocarbon vapors.

Taking the substances in the order in which we have placed them, those which must first claim our attention are the oils and resins. The former seem to have attracted the attention of experimenters at a very early period in the history of gas illumination, for, by referring to the records of the Patent Office, it is found that allusion is made to the generation of gas from oil so early as 1811. In 1815, Mr. Taylor, of the firm of Taylor & Martineau, obtained a patent for manufacturing gas from oil, and, under modification of this patent, gas-works were in operation at Bristol, Hull, London, Liverpool, Colchester, Dublin, and in several towns on the Continent. In conducting the process an iron retort was set over an ordinary furnace, by which it was to be heated. The retort was partially filled with fragments of brick, pumice-stone, or hard coke; above the retort was placed an horizontal cylinder or reservoir, or other suitable vessel, to contain the oil, and at the same time serve as an intermediate receiver for the gas and other products of distillation. The oil was made to trickle into the heated retort through a small tube near the front. Coming in contact with the heated surface of the bricks placed therein, a portion was speedily converted into gas or vapors; these latter, as they had to traverse the entire length of the retort, became in their turn converted into gas. This gas, together with any undecomposed matter, then passed into the oil cylinder through a pipe at the back of the retort. The permanent gas, passing afterwards through the cooling apparatus, and then to the gas-holder, the undecomposed oil, vapors, and tar remained in the cylinder, and mixing with the oil, were again conveyed to the retort, and thus the process continued until nearly the whole of the materials were converted into illuminating gas. A gallon of oil yields about 110 cubic ft. of gas of a specific gravity of not quite 700. The illuminating power of oil gas varies considerably, depending in a great measure on the temperature to which the retorts are heated. The author had occasion to use oil as a substitute for cannel for some considerable time, and he found the heat which gave the best results was what would be called a dull heat in a coal gas-work. Owing to the unprecedented increase in the price of coals for export, it is very possible that oil will be substituted for coal in many gas-works on the Continent, particularly in the olive-growing districts of Spain and Italy, the refuse from the oil-presses making very excellent gas.

About the time that Taylor was engaged upon his experiments with oil, other parties were turning their attention to resin as a material from which illuminating gas might be made; several companies were formed and works erected, both in this country and abroad, especially in the United States and Canada. Resin has been employed as a source of illuminating gas in a variety of processes, but the author will confine his remarks to two—one in which the resin is subject to simple dry distillation in an ordinary retort, and the second, where resin is employed to enrich feebly luminous gases. Under the first type the apparatus employed was originally invented by the late Professor Daniel, for the Resin Gas-Works, at Bow. In an ordinary oven two circular retorts are placed, so as to be heated by the furnace below. These retorts pass through the oven, and are open at both ends. The front end of each retort is bolted to a plate, the end of the mouthpiece passing through this plate, and is closed by an ordinary lid, cottar, and cross-bar screws. Flush with the outer edge of the mouthpiece an iron frame is fixed, fitted with a pair of sliding doors. The frame and doors leave a space

of about 6 in. between them and the brick-work of the oven. On the top of the oven, and immediately over the retorts, a tank or cistern is placed, and under the bottom of this cistern the heat from the oven is conducted on its way to the chimney. The back end of the retort extends about 9 in. beyond the wall of the oven, and to this end of the retort is attached a flanged mouth-piece, but the exit-pipe for the gas, instead of ascending as in coal-gas retorts, descends and communicates with a tank or cistern by means of a dip-pipe. This vessel occupies the place of the ordinary hydraulic main, the gas being conveyed from it through the coolers or condensers to the gas-holder. There is no necessity for using purifiers with resin gas. The mode of working the apparatus is somewhat as follows: The retorts being heated to a good cherry red, the resin, broken into small pieces, is placed on a perforated shelf, which occupies the upper part of the cistern placed above the retorts. The heat derived from the bottom of the cistern melts the resin, and it passes in a fluid state through the perforated shelf or sieve, and is allowed to flow down the two siphon tubes that are attached to the mouthpieces of the retorts, and placed within the inclosed space formed by the frame and sliding doors. The liquid resin passes into the retort by means of a slightly inclined trough or channel, and is thus made to fall on the surface of the red-hot lumps of fire-brick with which the retort is partially filled. The vapors given off by the liquid coming in contact with the heated surfaces pass along the whole length of the retort, and a large portion of them are converted into permanent gas. The undecomposed vapor passes along with the gas into the cistern or reservoir by means of the descending pipe, from whence the permanent gas escapes to the gas-holder, the residual vapors remaining behind in the shape of what is known as resin oil, which is pumped back into the resin cistern, where it acts as a partial solvent of the solid resin. In France and the United States, where resin gas has been more extensively employed than in this country, an apparatus, invented by a French engineer, named Chaussenot, has been worked with great success. It is more complicated than the one just described.

In 1867 the author was engaged in constructing works for the supply of gas to the city of Mexico. The original design for the works contemplated the use of coal, but the non-completion of the railway between the city and the seaport of Vera Cruz rendered it next to impossible to obtain a supply of coal at any reasonable price. The cost of land carriage between the port and the city being at the rate of 100 dollars, or £20 per ton. To meet the difficulties thus raised, an apparatus was designed by the author, in which either wood or water gas could be made and rendered of sufficient illuminating power by combining with it a portion of gas made from resin, or the mineral pitch called by the natives "chapapote," deposits of which occur in Sucatan and on the Isthmus of Tehuantefoce. The retorts were set over an arched furnace in the usual manner, with the exception that the area of the furnace was much larger, it being necessary to use wood for fuel. The retorts were circular, 13 in. in diameter, and 9 ft. 6 in. long, open at both ends. At the front end they were fitted with mouthpieces and lids, but instead of ascension-pipes, the two lower retorts were connected by short elbow-pipes to the mouthpiece of the centre retort. On the top of the oven, and immediately over the centre retort, was placed a small iron tank for melting the resin, or holding crude petroleum oil. The back ends of the retorts were fitted with mouthpieces, the two lower ones having ordinary lids, with screws and crossbars. The upper retort mouthpiece was closed by a flanged cover, to which was bolted a flange bend and pipe for the purpose of conveying the gas to the receiver or hydraulic main placed below the floor of the retort-house. In working the apparatus for wood gas, the two lower retorts were charged with a species of resinous pine called by the natives "Ocote." It is obtained by splitting up the stumps and roots of the pine trees after the main portion of the trunk has been cut down. (This wood yields about 11,000 ft. of gas to the 20 Spanish quintals, equal to 2,080 lbs. English, if carbonized at a bright red heat.) The gas from the two lower retorts was conveyed into the upper retort by means of the two elbow-pipes, where it underwent a further decomposition. It then escaped to the purifiers, and the illuminating power would average about 10 candles; but owing to the supply of ocote being very irregular, it not being possible to rely on the Indians who collected it, ordinary wood was oftentimes obliged to be substituted. This would only yield

about 7,500 or 8,000 ft. to the 2,000 lbs., and of very feeble illuminating power. To meet this difficulty the upper retort was converted into a resin retort, the resin being supplied from the cistern above. The gas from the wood mixed with the resin gas gave an illuminating power equal to about 12 candles; but the gases thus generated required a very costly process of purification to free them from the excess of carbonic acid and pyroligneous acid derived from the wood gas. The difficulty of getting rid of the impurities just mentioned led the author to devise a means for using the gases derived from the decomposition of steam instead of the wood gas; but it being next to impossible to obtain suitable apparatus in a country like Mexico, a plan was adopted by which the wood retorts were made to serve the purpose for generating the water gas. In each of the two lower retorts a cast-iron tube about 5 in. diameter was placed. This was filled with scrap iron, and supplied with steam through a suitable pipe. Round this tube, and nearly filling the retort, was packed charcoal and lumps of native "Tysoutle," or pumice, a species of volcanic cinder found in almost every part of Mexico. The other arrangements were precisely the same as for the wood and resin gas, except that the gas was conveyed into an ordinary hydraulic main, and passed through condensers, scrubber, and a set of lime purifiers in the ordinary way. The mode of working the apparatus was as follows: The steam entered the iron tubes, or decomposing chambers, and a portion of it was converted into hydrogen by coming in contact with the heated scrap iron. The undecomposed vapor was converted into hydrogen, carbonic oxide, and carbonic acid, by the charcoal and pumice. These gases then entered the upper retort, where resin gas was generated, the mixed gases afterwards passing to the condensing and purifying apparatus; but the process had to be abandoned on account of the large quantity of carbonic acid present, and the great cost of its removal. The resin and wood process was ultimately adopted, and the city of Mexico has been supplied for the last five years with gas made from these materials. It will be in the recollection of most of the members of the association that the hydrocarbon gas, patented by Mr. White, was essentially a combination of water gas with resin gas; but the process, although tried under the most favorable circumstances at Rio Janeiro, never succeeded, although Boghead cannel was substituted for the resin. It appears that the only circumstances under which resin can be used with advantage for the generation of illuminating gas are where resin is cheap and wood for fuel abundant. In practice only about one-half of the weight of crude resin can be converted into gas. The residue is condensed in the shape of oil at a bright red heat. The quantity of gas for weight of resin actually converted will average about 850 lbs. per 104 lbs., or about 18,000 ft. per ton English. The illuminating power of such gas will be about 14 standard candles. A very curious property the author observed in connection with resin gas is, that when used by itself it travels with great facility, and does not lose its light-giving constituents; but if mixed with other gases, a deposit of a thick viscid substance takes place on the inner surface of the pipes and fittings, through which the mixed gases may have passed. To this cause may be attributed many of the complaints that were raised against White's hydrocarbon gas when it was first introduced.

The materials next in importance which have engaged the attention of experimenters in the manufacture of illuminating gas are the mineral oils, either in their natural state or as derived from treating shales or bituminous schists, and some varieties of asphalts or mineral pitch. These substances, like resin, have been either used directly for the generation of gas, or have been used in combination with non-luminous gases. Within the last 10 or 15 years many patents have been taken out for processes or apparatus for the destructive distillation of these mineral oils, but up to the present time no process has been sufficiently successful as to secure for itself any general recognition. In Germany and the United States some of the attempts made to use crude petroleum have met with comparative success. The one which the author believes to be the best is the invention of a German chemist, Dr. Herch. The apparatus consists of a circular retort set in the usual manner. The retort is fitted with a mouthpiece and lid at each end. The front mouthpiece is connected to a large cylindrical chamber or receiver by a taper pipe, which is substituted for the ordinary ascension-pipe. At the back of the retort is placed a small

cylindrical vessel or chamber fitted with a cover and stuffing-box. In the interior of the chamber a weighted piston or plunger is placed, the rod of which passes through the stuffing-box. To the upper end of this rod a cord is fastened, which passes over a series of compound pulleys, and the end connected with a train of clockwork machinery. From the bottom of the box or chamber in which the piston is placed a small tube or pipe is connected with the lid at the back of the retort, and from thence a small taper tube projects, into the interior of the retort. The process of manufacturing the gas is as follows:—The chamber or cylinder in which the plunger is placed is filled with the petroleum or mineral oil until the plunger has risen to the top. The cord is then coiled over the pulleys, and the end attached to the clockwork. As soon as the retort is sufficiently hot, the pendulum of the clock is set in motion, and the cord is gradually uncoiled. This liberates the plunger or piston, and thus the liquid in the cylinder is forced through the small connecting-pipe and taper tube into the retort, where it is distributed in a very thin sheet over the heated surface. A considerable quantity of the vapor is thus converted into gas, and is conveyed by the large taper pipe into the vertical receiver. Here the gas and vapors are separated by the cooling effect of the receiver, the permanent gas passing to a suitable gas-holder, the condensed vapors, in the shape of tar or oil, fall to the bottom of the receiver, and are drawn off and returned to the first cylinder, when a fresh charge of oil is put in. The process is exceedingly ingenious, but the author is not able to say what the result of the experiment has been in a commercial point of view. In the United States many forms of apparatus have been tried, but most of them have failed on account of the great difficulty of getting rid of the rapid deposition of soot or solid carbon on the surfaces of the retorts, or the materials placed within the retorts to effect decomposition. It is found in practice that a comparatively thin layer of this finely divided carbon materially interferes with the process of decomposition, and the result is that when an apparatus has been at work for only a short time, it happens that the make of gas is reduced 50 per cent. If some arrangement could be invented by which this deposit could be prevented, there is no doubt that the mineral oils would be found most useful substitutes for cannel coal in the production of gas of high illuminating power.

Before entering upon a description of some of the processes in which mineral oils are used in combination with non-luminous gases, the author will briefly describe the system proposed for using wood and peat as gas-making materials. The use of wood for the manufacture of gas appears to have been suggested at about the same time as coal was being experimented upon. In the mechanical museum at Paris the author has seen the sketch and description of an apparatus invented in 1790 by a person named Lebon. It was evidently intended to compete with the invention of Mr. Murdoch, who was then engaged upon his experiments with coal gas at Redruth, in Cornwall. It does not, however, appear that Lebon's process was ever used beyond lighting his own house, as no mention is made of the introduction of gas-lighting into France until 1815. After Lebon's invention, the first attempts to use wood for gas appear to have been made in Russia; but it was not until the experiments of Dr. Pettenkofer, of Munich, were made public in 1849, that any attention was given by gas engineers to the use of wood as a gas-making material. Since that time several cities and towns in Germany, Russia, and the north of Europe, have been supplied with gas manufactured from wood.

In 1865 the author visited Germany for the purpose of making himself acquainted with the various processes then in operation for manufacturing gas from wood. He visited the works of Marburg, Darmstadt, Wurzburg, and Munich. The apparatus employed was the same as for coal gas manufacture, with the exception of one or two instances, where the ascension-pipes were cased and the hydraulic main was made double, leaving a space of 2 in. between the portion of the main into which the gas and products of distillation passed and the outer casing. The annular space between the two mains was filled with steam or heated air. It appeared that an essential condition for the success of the process was that the wood should be thoroughly dried or baked before being put into the gas-retorts, and that the temperature of the retorts should be maintained at a bright cherry-red heat. The illuminating power of the gas varied considerably, leading to the conclusion that in some instances

a process of carburation was resorted to. An apparatus, designed for a town in the north of Russia, used the wood gas simply as a diluent, and made the illuminating power entirely dependent on its saturation by the vapors of naphtha. The apparatus used for carburetting has just been reproduced in this country by the patentee of the so-called "new gas."

The illuminating power of wood gas seems to depend very much on the quantity consumed. In practice it is found that a coal gas-burner consuming 5 ft. per hour, and giving the light of 13 candles, will with the same consumption of wood gas only give the light of nine candles; but with a burner consuming 7½ ft. per hour, the light from the wood gas will be 17.43 candles, as against 18.27 for coal gas. Mr. Riedinger, the engineer of the wood gas-works at Coburg, gives as the results of his experiments, that wood gas is 22 per cent. cheaper than coal gas, if the wood be taken before the essential oils have been extracted, and it is thoroughly dried before being subjected to distillation. The author found that by passing the gas through a second retort, heated to redness, the illuminating power of the gas was considerably improved. This is, no doubt, due to the decomposition of some of the oxides of carbon; but, unfortunately, the cost of purification was considerably increased owing to the larger quantity of carbonic acid that was present in the gas. The author, however, believes that if suitable precautions be taken in thoroughly desiccating the wood, there are many localities where wood gas might be used with advantage, especially if lime be cheap and abundant. What has been said in reference to wood will more or less apply to the use of peat as a gas-making material. At the present time a series of experiments are being made with peat which has been saturated with the refuse of shale oil distillation; but as the details of the experiments have not been made public, no opinion can be formed as to the merits of the scheme. Several other processes have been suggested for using animal and vegetable substances in the manufacture of illuminating gas; but as none of them have been carried beyond the stage of laboratory experiments, it is not considered necessary to enter into any details respecting them. The author, therefore, now proceeds to review the plans that have from time to time been brought forward to produce illuminating gas by the admixture of non-luminous but combustible gases with some form of volatile hydrocarbon.

The possibility of utilizing the effect produced by the action of heated metal on water in connection with the manufacture of gas appears to have been first suggested by the late eminent gas engineer, George Lowe, Esq. In a letter written by that gentleman to the "Philosophical Magazine" of Nov. 14, 1818, he describes his experiments at Derby. In speaking of the use of iron tubes filled with scrap iron, and heated to redness, he makes this remarkable statement: "But by passing the tar and water of crystallization through iron turnings, or over any oxidizable surfaces, the two are nearly all converted into gas, and come over with the hydrogen of the latter, which has been liberated at the expense of the iron turnings, and to me it is evident the great increase arises infinitely more from the decomposition of the water than of the tar." Twelve years after the experiments of Mr. Lowe we have the patent of Mr. Donovan, of Dublin, and a year or two afterwards the process of Mr. Saunders. These, in conjunction with the process described in the patent of Mollerat, may be said to have been the foundation of all the subsequent inventions employed for the decomposition of water by passing its vapors over heated surfaces. It is true that the precise form of apparatus has been modified in accordance with the views of each particular experimenter, but the essential principles involved in the process are throughout the same. To describe the mode of manipulation in general terms, it would be somewhat as follows: Two or more tubes or retorts are set over an ordinary furnace by which they can be heated to the required temperature. These retorts are partially filled with scrap iron, or in the case of several retorts being set together, one retort may be filled with scrap metal, and the remainder may be partially filled with charcoal or coke. As soon as the retorts are heated to the temperature required (which should be a bright red by ordinary daylight) a stream of water or steam is injected into the retort containing the metal. Here the vapor is to some extent decomposed, the oxygen of the water being taken up by the heated metal, which thus becomes rapidly oxidized. The other constituent of the water, the hydrogen, is carried forward, along with any undecomposed vapor, and enters the retort or

retorts containing the charcoal or coke. And here a considerable portion of the remaining vapor is decomposed, the resultant gases being hydrogen and the two oxides of carbon, as carbonic oxide and carbonic acid; the gases, therefore, escaping from the last retort consist of partially pure hydrogen, carbonic oxide, and carbonic acid, with some sulphuretted hydrogen and traces of bisulphide of carbon, the two latter due to the sulphur derived from the coke and impurities in the scrap iron. The gases, after leaving the retort, undergo refrigeration, thus separating them from any undecomposed vapor. They then pass through suitable purifiers to remove the excess of carbonic acid and the sulphur compounds. The gases so purified are rendered luminous by bringing them in contact with the vapors of some volatile hydrocarbon. In the earlier experiments highly rectified oil of turpentine was employed; but the discovery of benzole, by Professor Faraday, led to the more volatile compounds derived from coal tar, naphtha being substituted for the essential oils in the carbonization of what was called the water gas.

Illuminating gas made by the process just described, was tried in several towns in this country, Ireland, and on the Continent, but in all cases resulted in signal failure, as it was found impossible to compete with the simpler process of manufacturing gas from coal. About the year 1834 or 1835, considerable attention was drawn to a water gas process, patented in France by M. Selligue, in which a considerable modification of the decomposing process was adopted, inasmuch as the water vapor was conducted first into vessels or retorts containing charcoal, where it was converted into hydrogen and the oxides of carbon; in a third retort the gases so formed came in contact with the vapors of shale oil, and as this retort was nearly filled with iron chain or scrap, a considerable decomposing surface was exposed, and a large quantity of very superior gas said to have been obtained. But on subjecting the process to strict chemical investigation, it was found that some questionable proceedings had been had recourse to in carrying out the first experiments; when the chemist's report was presented, the whole affair collapsed. From 1835 to 1849, a great number of schemes were brought forward, and some patented for improvements in the manufacture of water gas, but none appear to have succeeded.

In 1850 a new process was brought forward by an American inventor named Paine. He proposed to generate pure hydrogen from water by the aid of a magneto-electric machine, and convert it into illuminating gas by passing it through camphene. The most marvellous results were claimed for this invention, and a monster apparatus was prepared for the Great Exhibition of 1851, but the author believes that owing to the matter having been placed in the hands of Mr. Faraday, the fallacy of the so-called invention was exposed, and nothing more was heard of it. The well-known process of Mr. White for the production of hydrocarbon gas was at this period before the gas world; but as it resolved itself ultimately into a modified coal process, it will not be consistent with the object of the present paper, to make more than this passing allusion to it.

The enormous increase in the production of hydrocarbon oils, due to the discovery of the oil and petroleum springs on the continent of America, has given fresh impetus to the class of inventions which seek to substitute these oils for coal in the manufacture of gas. The direct destructive distillation of these oils has already been alluded to, but the utilization of the highly volatile vapors derived from the process of distilling these oils for general purposes has revived the idea of generating combustible gases by the decomposition of steam or water vapor. Of the several so-called inventions of the last four or five years, the only one which appears to present any new features is the one claimed by a Frenchman named Du Motay. It was originally intended as a process for the production of hydrogen to be used in connection with the oxyhydrogen light, but in its modified form is being used in producing illuminating gas from hydrocarbon vapors.

The process may be described as follows: Superheated steam is injected into a large retort or decomposing chamber filled with charcoal or coke, and heated to redness; here the vapor or steam is converted into hydrogen and carbonic oxide. From this mixture the carbonic oxide is removed by passing the gases through cylinders of hydrated or slaked lime heated to redness. The result of this treatment is the formation of a fresh equivalent of hydrogen, and the conversion of the carbonic oxide into carbonic acid by union with the oxygen of the decomposed water of hydration. The carbon-

ic acid is removed by passing through more lime, and the hydrogen is passed on into another chamber, where it comes into intimate contact with a quantity of light petroleum spirit; here it loads itself with the vapor of the hydrocarbon, and continues on its course, passing next through a series of iron tubes heated to a low red heat, whereby a permanent gas is formed, precisely analogous in all its properties to the ordinary coal gas, but of considerably higher illuminating power. This invention has recently been in operation in the United States, and very favorable reports have been given as to the results, but no reference is made to the question of cost.

One of the old processes for manufacturing water gas has just been repatented in this country by a Mr. Ruck, who claims for it the title of the "New Gas," but in what the novelty consists it is difficult to discover. In this process it is proposed to use superheated steam, and the manipulation is somewhat as follows: A bench of three or more retorts up to nine are set in, more or less, the ordinary manner. Alongside the top retort (which is considerably larger than the others), and within the oven, are two cast-iron tubes or pipes, connected by an arch-bend, which passes over the top of the retort. If three retorts are set, this tube or tubes are made to communicate with the two lower retorts by means of cast-iron pipes and suitable connections to a pipe which lies along the bottom of each retort inside, and extending to within a few inches of the back of the retort. From the mouthpieces of the bottom retorts two branch pipes lead to pipes which lie along the bottom of the top retort, also to within a few inches of the back. The two bottom retorts are partially filled with scrap iron, or pieces of chain, mixed with a portion of coke or charcoal. The top retort may also be partially filled with coke or charcoal. Communicating with the flange-pipes alongside the top retort a steam pipe from any ordinary steam boiler is fixed, capable of being closed at pleasure by means of a stopcock or valve. The retorts being heated to the required temperature, steam is admitted to the flange-pipes, where it becomes superheated. In this condition it passes to the two lower retorts through the pipes laid along the bottoms, and, escaping at the back of the retort, it then comes in contact with the heated metal, or charcoal, or coke, and a portion of it becomes converted into hydrogen and the two oxides of carbon. These gases, with the undecomposed vapor, then pass into the top retort through the branch pipes just described, and a further decomposition takes place. The resultant gases are then cooled and purified from sulphuretted hydrogen, and a small portion of the carbonic acid is taken out, and the mixed gases then are made to bubble through a quantity of light hydrocarbon spirit contained in a closed tank. This part of the apparatus is identical with the carburetting arrangement of the Russian wood gas, previously described, but in order more readily to volatilize the heavier descriptions of petroleum spirit a current of warm air or steam is conveyed to the spirit-tank to maintain it at a suitable temperature. From the description just given it will be evident that the principle of the process is identical with all the previous inventions, so far as the means employed for the decomposition of the water vapor is concerned. It is true the patentee lays considerable stress on the use of superheated steam, but it is very questionable if there is any real importance to be attached to this part of the process. The intrinsic value of any of these inventions rests in the quantity of combustible gas that can be generated by the consumption of a given weight of fuel, and as the quantity of hydrogen to be thus obtained is the point of principal importance, it will be evident that the greater the weight of water decomposed by a given weight of fuel the more valuable the process becomes. For every 9 lbs. of water completely decomposed 180 cubic ft. of hydrogen will be liberated. The proportions of carbonic oxide and carbonic acid will, however, vary according to the heat at which the process is carried on. The quantity of water gas produced by the consumption of a given weight of fuel varies considerably with the nature of the fuel employed. From a great number of experiments made by the late T. G. Barlow, Esq., the quantity of coke consumed per 1,000 ft. of water gas was found to average 60 lbs. In the author's experiments at Valparaiso, using the coke from a mixture of Australian and native coal, the average was found to be 73 lbs.; with charcoal, 104 lbs.; and with ordinary wood fuel, 127 lbs. per 1,000 ft.; and these are the results of experiments extending over several months. Mr. Barlow, in some instances, found that retorts making more than 600 ft. per hour

when first put into action gradually reduced in make to 352 ft. per hour, and the average of a day's working was sometimes not more than 330 ft. per working hour. Increased wear and tear occurs, due to the rapid oxidation of the interior of the retorts. This effect was fully shown in Mr. White's hydrocarbon process, and has been confirmed by all subsequent experimenters. The average duration of a water gas retort is about 210 days, where a combination of scrap iron and coke or charcoal is used; but if scrap iron be used alone, from 170 to 180 days will be the maximum duration of such a retort.

Another important matter which requires consideration is the purification It has already been shown that water gas is always contaminated with a very large quantity of carbonic acid, and more or less sulphuretted hydrogen, the latter increasing where coke is used instead of charcoal in the decomposing retorts. Supposing the process of purification be by lime, then the cost must be very great, because, from the greater affinity which caustic lime has for carbonic acid than for sulphur, it is obvious that the lime would absorb all the carbonic acid before it acted at all on the sulphur, and the removal of the sulphur compounds would depend on the amount of caustic lime left after all the carbonic acid had been taken up. If oxide of iron be used without lime, then the carbonic acid would remain, and of course materially diminish the illuminating power of the gas. It is suggested by the promoters of the "new gas" that the presence of carbonic acid might be commercially disregarded in estimating the value of the process, but in experimenting with gas made in the manner proposed, it is found there is a loss of nearly two-thirds in illuminating power when the carbonic acid remains in the gas. The same class of spirit burnt in combination with pure hydrogen gave $31\frac{3}{10}$ candles, with unpurified water gas only $11\frac{7}{10}$ candles. The deduction the author draws from these facts is that the cost of purification must always form an important element in estimating the value of any water gas process.

If the description here given of the so-called "new gas" be a fair one, it is evident that such a process can never come into competition with coal except under very special conditions; in fact, the circumstances would be so exceptional that they can never occur in any country where coal is the staple source of fuel. In some countries, perhaps, where wood fuel is abudant, and petroleum or other mineral oils easy to obtain, it is possible such a process of obtaining illuminating gas might be successfully applied; but under the most favorable conditions such a process would have to contend against the disadvantages inherent to the use of a manufactured material instead of a raw one, and the risks of interruption in supply, or the certain loss that must always take place in storing such volatile materials as these light hydrocarbons are.

Proposals have recently been made to construct a special class of steam vessels to convey to this country the kind of spirit it is proposed to employ in some of these hydrocarbon processes. The model of a vessel is now being exhibited in London, fitted with tanks having a capacity for many thousand gallons of the spirit. By a very ingenious arrangement of floats and valves and spare tanks, the effect of expansion due to variation of temperature is provided for, and all risk of explosion avoided, although the tanks are hermetically sealed. A company has been formed in the United States to provide the necessary apparatus and store tanks for collecting this highly volatile spirit, and it is assumed that a quantity equal to about 200,000 lbs. will be collected during the year. Supposing the whole of this material to be shipped to England, the quantity available for the manufacture of illuminating gas, after allowing for loss in transit and other contingencies, is estimated at about 7,000,000 gallons—a quantity sufficient to manufacture about 400,000,000 cubic ft. of 24 to 25 candle gas.

The author now proceeds to a partial consideration of those processes in which air is to be made the vehicle for conveying the combustible material for the production of illuminating gas. This idea was suggested many years ago by the late Mr. Beale, of East Greenwich, and Mr. William Maugham, the well-known lecturer on chemistry. The whole of the apparatus was contained in a portable lamp, but it was found so difficult to manage, and the smell from the naphtha vapor so disagreeable, that the invention never came into general use. Some years afterwards the late Mr. Mansfield took out several patents for lamps in which a current of air was drawn through a reservoir filled with benzole, and thus became saturated with the hydrocarbon vapor; the air

thus charged was then consumed like ordinary gas. During the exhibition of gas apparatus held in 1851, several contrivances were shown for carburetting air. One, the invention of an American engineer, was frequently explained at the lectures given at the Polytechnic Institution. In 1854 the author made a series of experiments with an apparatus patented by a Mr. Longbotham, of Leeds. This invention consisted of a pair of bellows set in motion by a small steam engine. The current of air from the bellows was forced through or over pumice-stone saturated with oil of vitriol so as to render it thoroughly dry; it was then driven into a vessel containing highly rectified coal tar naphtha and benzole, in which gum resin had been dissolved; the air when saturated with the vapor then passed into a gas-holder, from whence it was conveyed to burners in the ordinary manner. In the course of these experiments it was discovered that air gas requires burners with very large apertures to burn it properly, for any undue pressure causes the vapor to separate from the air. Another matter was the fallacy of the test of permanency. By simply allowing the gas to remain at rest in a gas-holder, the same gas tested from the gas-holder showed scarcely any loss of illuminating power; but after passing through 120 ft. of pipe, it was found to have lost nearly 20 per cent. Another circumstance to which attention was drawn is perhaps worth mentioning: it was that the deposition of hydrocarbon vapors increases with the quantity of gaseous material passing through a given length of pipe. This appears to arise from the want of homogeneousness in the structure of the vapors themselvers. If air or combustible gas saturated with these dense vapors is made to pass through a long length of pipe, at first only a very slight deposit will be observed, but in the course of a short time a film of viscid matter will be found to have collected on the inner surfaces of the pipes; this film gradually increases, and after a time it will be found that a considerable quantity of liquid has accumulated from the vapors retarded by this viscid film. Gas engineers are all more or less acquainted with the effect produced by similar viscid deposits in the formation of naphthaline in coal-gas mains. In 1866 the author visited the United States, and while there had the opportunity of seeing a variety of processes for the carburetting of air; these were called gas machines. Most of these machines have been reproduced in this country under one title or another. Within the last six or eight months, nine patents or proposals for patents have been brought forward, based on the principle of saturating air with highly volatile vapors; but as they all involve the same general character, they all possess the same inherent defects—namely, want of permanency or danger of explosion. The former defect is due to the variable character of the oil or spirit used for carburetting the air. The higher the specific gravity of the spirit, the more unstable are the vapors. The author has found some samples that would give off vapor freely at a temperature of 60 deg., but would deposit 40 per cent. of their volume if the temperature were reduced to a little above 45 deg. As the specific gravity of the spirit becomes lower, of course the vapor is given off at a correspondingly lower temperature; in fact, in some samples of spirit with which recent experiments have been made, the vapor was found to be permanent considerably below the freezing point of water. The danger from explosion appears more to arise from the want of a proper quantity of vapor in the air than from the direct explosive property of the spirit itself. In the United States, where the most serious accidents have occurred, the causes of explosion have been shown to be the excess of air, either from the undue escape of spirit from the saturating vessel, or the effect of sudden and intense cold in checking the evaporation of the spirit, or, as has been the case in several instances, the adulteration of the spirit with a portion of heavy oil. But the risk of accident has become so great that a police ordinance has been promulgated at the instance of the American Insurance Societies prohibiting the use of *gasoline*, as this spirit is called, except in conformity with certain special regulations, such as the following:—"That no reservoir containing the spirit is to be allowed to be placed above the ground. That no such reservoir is to be placed within a distance less than 30 ft. of any dwelling-house or enclosed building. That no reservoir is to be filled with gasoline after sunset or before sunrise. That no reservoir is to be made of any material but metal, and to be capable of being hermetically sealed."

One of the most recent modes of producing air gas is by making use of the weight of these vapors to induce saturation. A

vessel containing some fibrous material is saturated with the hydracarbon oil. To the lower end of this vessel a pipe is attached, terminating in an Argand burner with stopcock. On the top of the vessel an aperture is made that can be closed by a metal cap. When the light is required the cap is removed, and the top of the burner is opened, a current of air is drawn through the saturated material contained in the body of the vessel by the descent of the heavy vapor, and on applying a light to the burner a very rich gas flame is produced. This arrangement is said to be the invention of Professor Greenhous, of the United States, who claims to have discovered a means of rendering these light oils non-explosive; some startling experiments have been exhibited, but the author is not quite sure that the results were due to any special chemical preparation, or to the dexterity of the manipulator. If Professor Greenhous has discovered any method by which the volatility of these substances can be controlled, there can be no question but that he has conferred new value on these hitherto dangerous bodies.

In bringing this paper to a conclusion, the author would observe that he has purposely avoided any allusion to processes in which the distillation of coal enters, because he felt that the mere mention of the list of inventions embracing the partial use of coal in combination with some form of hydrocarbon would have extended the subject beyond all ordinary limits; he has, therefore, confined himself to the consideration of such materials and processes as could be employed in the production of illuminating gas without the use of coal under any form whatever.

And now, without for one moment disparaging the efforts of those who from time to time come before the public with suggestions for improving the manufacture of gas, either by destructive distillation or by a combination of chemical processes, he believes he is warranted in coming to the following conclusions:—

1. That no material or process invented or brought forward up to the present time can compete with coal in the manufacture of illuminating gas, except in countries or localities where coal cannot be obtained.

2. That the substances most suitable for the manufacture of gas are those from which it can be obtained by direct distillation, as in the case of oils, resins, and woody fibre.

3. That no process of gas manufacture can be considered successful where the resultant gases are not readily purified, or, where, after ordinary purification, they contain an excess of substances injurious to animal life.

4. That no mere carburetting process can be commercially successful until some form of hydrocarbon is discovered that is perfectly homogeneous in its chemical structure, and that can be rendered sufficiently non-explosive as to admit of its being transported from place to place or stored with comparative safety.

EXPLOSIVE AGENTS APPLIED TO INDUSTRIAL PURPOSES.*

By FREDERICK AUGUSTUS ABEL, F.R.S.

The almost complete monopoly which gunpowder has, until quite recently, continued to enjoy, as the explosive agent applied to industrial purposes, is not ascribable to any lack of attempts to supplant it in its various uses. It is due partly to the low price at which mining or blasting powder is manufactured, but principally to the almost universal familiarity with its employment and general effects, and to the confidence in the unchangeable nature of its behavior and properties, which are the natural results of its great antiquity and of the remarkable fact, that the most strenuous and persevering efforts to attain, by other explosive agents, the results which it furnishes in some of its most important applications (especially connected with war purposes), have hitherto proved unsuccessful.

As gunpowder is simply a mechanical mixture, in variable proportions, of certain solid substances which are capable of reacting upon each other chemically, the result being the partial transformation of the solid mixture into gaseous matter and the development of great heat, it follows that the explosive force which such a mixture is capable of exerting is liable to considerable

* Proceedings of Institution of Civil Engineers.

variation. Thus, it may be regulated by the following circumstances, either separately or collectively: the proportions in which the ingredients are employed, the degree of intimacy or completeness with which they are mixed, and the mechanical condition or form which the mixture has taken. This liability to a variation in explosive force or strength, though it constitutes an important advantage with respect to some of the uses of gunpowder, has an undoubtedly detrimental effect upon its value in many of its applications to industrial purposes, and upon its position with reference to other explosive agents, inasmuch as it has caused competition to effect such reductions in the cost (and consequent perfection of manufacture) of mining or blasting powder, as to diminish greatly the results attainable with the ordinary descriptions of powder sold under those designations. Gunpowder has certain defects which are inherent in the material: thus, it is liable to deterioration by keeping, in consequence of the absorption of moisture; and this is especially the case with powder made for mining purposes, because this powder is more porous, and less carefully finished, than war powder, and also because it is generally made with only imperfectly refined, or even with unrefined, saltpetre. The quantity of smoke produced by the explosion of powder is a source of inconvenience and loss of time in underground blasting operations; and the circumstance, that if gunpowder becomes ignited from any cause it must explode violently, is a constant source of casualties in mining districts. The proposal to render gunpowder safe in store by diluting it, or interposing inert materials between its grains, which was revived by Mr. Gale, in 1865, has not found favor, for reasons which cannot now be discussed; but it may be hoped that careful legislation will shortly tend to reduce the number of accidents, which arise in this country chiefly from the almost inconceivable recklessness displayed in the storage and handling of gunpowder by its vendors in mining localities. Even then, however, the casualties due to neglect of ordinary precautions, or to the extreme carelessness of those using gunpowder in mines and quarries, are hardly likely to be reduced in number.

The successful employment of tunnelling machines within the last few years has demonstrated more forcibly than could otherwise have been done, the great advantage, in saving of time, which must accrue from the employment of a more powerful blasting material than common gunpowder. But even in many ordinary blasting operations, there is no difficulty in showing that an important saving of time and labor may be effected in many kinds of work by employing a more powerful explosive agent than blasting powder; the possibility of using blast holes of reduced dimensions, and of increasing their distance from each other without detriment to the magnitude of the results, being advantages of the most obvious description. It appears to have been repeatedly demonstrated by practical trials, that, in the removal of hard rock, in tunnelling, and in other operations of this class, decided advantages are gained in point of rapidity of work, by the employment of gunpowder of higher quality than ordinary mining powder; but those advantages will not bear comparison with the results attainable by the employment of certain explosive agents of a decidedly more violent character. There are, however, some directions in which ordinary blasting powder does not appear to be replaceable with advantage, if at all, by the explosive agents which are formidable rivals to it in other directions.

Before discussing the substances which have been proposed and employed as substitutes for gunpowder in industrial operations, it may be advisable to refer in very few words to the action of that substance, and others of a similar nature. The explosive properties of a mixture of saltpetre, charcoal, and sulphur, such as gunpowder, are primarily due to the powerful oxidizing power of the nitric acid compound known as saltpetre (or nitrate of potash), or, in other words, to the rapid and energetic manner in which oxidizable substances (such as carbon) are burned by the oxygen, of which saltpetre contains a large supply, held in feeble combination, and therefore ready at any time to enter into more stable combinations with other substances, when conditions favorable to chemical change are fulfilled. Nitric acid itself, in the free state, possesses this same property of violently attacking oxidizable bodies, and combinations of that acid with other metals (*e.g.*, sodium and barium) are obviously also endowed with similar oxidizing power. The violence of explosions developed through the agency of these substances depends upon the energy and rapidity with

which they attack oxidizable substances, upon the volume of gas or vapor rapidly or suddenly liberated by the chemical change, and upon the heat developed by that change. It also depends, in some measure, and to a variable extent, upon the conditions under which the chemical reaction between the substances constituting the explosive mixture is developed.

The oxidizing properties possessed by nitric acid and the nitrates are shared by numerous other bodies known to chemists, among others by a class of compounds of analogous nature to the nitrates, known as chlorates, in which the large supply of oxygen is held in comparatively very feeble combination by chlorine, as in the nitrates it is held combined by nitrogen. The chlorates are much more readily decomposed, and are therefore more powerful oxidizing agents, than the nitrates, and hence, when mixed with oxidizable substances, such as carbon and sulphur, they furnish more violently explosive mixtures.

Ever since the chlorate of potash has been produced upon a manufacturing scale, attempts have been made from time to time to utilize its comparatively violent oxidizing power in the production of explosive mixtures more powerful than gunpowder, and applicable to its various uses.

Preparations consisting of chlorate of potash mixed with certain sulphides, with the prussiates of potash, with sugar or starch, these substances being either employed alone or in admixture with sulphur and other substances, have been brought forward at various times, and under a variety of names, as gunpowder-substitutes, the earliest of them being known as German gunpowder, and white gunpowder; but the property which they all possess, of being exploded when submitted to comparatively moderate friction or percussion, was alone sufficient to prevent their being accepted as practically useful explosive agents, even if decided advantages could have been established for them by a proper comparison of their cost and efficiency with those of gunpowder. Ingenious attempts have been made to reduce the dangerous nature of chlorate of potash-mixtures by impregnating or covering them with inert materials designed to serve as protective agents, by absorbing or deadening the violence of blows, friction, or concussion to which they might be subject; but, while such contrivances were only partially successful in guarding against liability to accident, they so considerably reduced the rapidity and violence of explosion of the materials to which they were applied, as to preclude these from competing successfully with powder from an economical point of view.

A few comparatively safe preparations containing chlorate of potash have, however, been devised, some of which have furnished results in competition with powder, as mining and quarrying agents, so far favorable as to render it probable that they would have met with somewhat extensive application, but for the practical development of another class of explosive agents, which have within the last few years become formidable rivals of gunpowder. These chlorate-preparations are of several descriptions; one kind consists of mixtures of the salt with organic substances containing, in addition to carbon, a considerable proportion of hydrogen, such as powdered nut-galls, tannin, and resins. The preparation of powdered nut-galls and chlorate, known as Horsley's powder, which may be considered the type of these mixtures, has been found in practice to possess decided superiority over gunpowder in regard to violence of action, and to be much safer than any chlorate-preparation previously used. Another preparation, in which chlorate of potash was applied with comparative safety to blasting and other purposes, was first devised by Messrs. Hochstädter in 1860, and subsequently reproduced with slight modification by M. Reichen. Strips of bibulous paper were soaked in a pasty mass consisting essentially of a mixture of chlorate of potash, saltpetre, charcoal (and small quantities of other readily oxidizable substances), together with a little gum or other binding material dissolved in water. The paper became coated with the explosive mixture, and, at the same time, impregnated with the oxidizing salts, of which it absorbed part of the solution; the strips were rolled up tightly while wet, and when dry furnished hard and compact cylindrical masses, which were violently explosive when confined, but resisted detonation to a very high degree when submitted to percussion or friction.

Some other comparatively safe applications have been made of chlorate of potash to the preparation of explosive agents for mining purposes, by only partly replacing saltpetre with it in mixtures of similar

composition to ordinary gunpowder, or containing sulphides besides free sulphur. A substance called Tutonite, for which special advantages as a blasting agent have recently been claimed, appears to belong to this class of preparations. It possesses the peculiarity of being made up in the form of somewhat hard pellets or disks, instead of being in the granulated or pulverulent form.

A few explosive agents have been applied as substitutes for gunpowder (and proposed in the first instance purely for industrial purposes) which present this peculiarity—that their claim to consideration has been based, not, or only in a minor degree, upon superiority in point of power, but upon special advantages in point of economy, safety in manufacture and use, and peculiar fitness for employment as blasting agents. One of these was specially a "safety-powder," devised by Messrs. Kellow, and manufactured near Plymouth a few years ago. It consisted of spent tan and sawdust, which were saturated with saltpetre or nitrate of soda and a little chlorate of potash, the product being afterwards very crudely mixed with sulphur.* This preparation simply deflagrated with some difficulty when set fire to in open air; but when used with tamping, in the ordinary way, it appears to have competed very fairly with blasting powder. Another blasting agent of this class was invented in 1862 by a Belgian officer, Captain Wynants, and consisted of a mixture of charcoal and nitrate of baryta either alone or with a proportion of saltpetre. The objects aimed at in producing this "poudre barytique," or "saxifragine," were, in addition to economy, the production of a powder which should act with gradually accumulating force, and which should only be applicable as a blasting powder, so that supplies placed in the hands of miners could not be diverted to other purposes. The first-named object was certainly attained, the baryta-powder being comparatively very slow-burning; and its special characters are such that its application could not but remain limited to ordinary mining and quarrying uses, although its inventor did after a time propose that it should be applied, by admixture with ordinary cannon-powder, to moderate and regulate the pressure exerted by heavy charges in guns of large calibre; a result which has been attained with great success, and in a more philosophical and practically efficient manner, by simple modifications of the physical and mechanical condition of ordinary gunpowder.

It may not be out of place to refer briefly to the fallacious belief, which appears to be frequently entertained by inventors of explosive agents for blasting purposes, namely that a material which is capable of competing successfully with powder, or of maintaining a superiority over it, in mining operations, must also possess corresponding points of superiority over gunpowder applied to artillery, small arms, and other war purposes. Less smoke, less fouling, and greater penetrative power are points of superiority often claimed for preparations, which, like the mixture of chlorate of potash with nut-galls and similar products, are to some extent successful rivals of gunpowder in its industrial applications, but which cannot be made to combine the comparatively gradual action of powder with the uniformity essential for artillery or small arms. A high explosive power is, furthermore, not the only essential qualification of a powder or other preparation to be employed in shells or in military engineering operations. Freedom from liability to explosion by the violent concussion to which a shell is exposed in the bore of a gun; safety in transport and during manipulations by which the material may be subject to friction or concussion, are among the most indispensable conditions to the application of the explosive agent to service purposes, and are not to be set aside by the impracticable alternative, almost invariably suggested as an important advantage by the proposer of a new explosive mixture, namely, that of keeping the ingredients, which in themselves are harmless, separate until just before the material is required for use, thereby postponing any risk of accident, but accumulating it within a period when it can least readily be guarded against, and resorting to wasteful expenditure of sources of force, in the shape of crude mixtures, as a means of partially counteracting those very properties which render the material specially valuable when applied to its legitimate uses.

One other class of explosive mixtures, of which either saltpetre or chlorate of potash is an essential ingredient, must be briefly referred to, because, though their applica-

* A blasting powder, now being manufactured under the name of "Pyrolithe," bears the close resemblance to Kellow's powder in its composition.

tion to blasting purposes has only been attempted to a limited extent, they have lately attracted some attention, as being agents of considerable power.

Among the numerous products obtained by the action of nitric acid upon materials of organic (animal or vegetable) origin, one of the earliest discovered possessing explosive properties is the product known as picric acid, or carbazotic acid, which is furnished in that way by indigo and various other organic substances. Though discovered in 1788, it was only prepared in small quantity until within the last twenty years, but it is now readily manufactured from the coal-tar product known as carbolic acid, and has recently become an important article of commerce as a cheap and brilliant yellow dye. Its salts are all more or less explosive, the picrate of potash, one of those most easily prepared, being especially so. This, when mixed with saltpetre or chlorate of potash, particularly with the latter, furnishes products which, in violence of action, more nearly resemble gun cotton and nitroglycerine-preparations than does any other readily procurable explosive agent. Both mixtures are susceptible of detonation by friction, and especially that containing chlorate of potash, which is indeed inapplicable to practical purposes on account of its dangerous nature. M. Designolle devoted considerable attention, a few years ago, to the production of safer mixtures of picrate of potash for artillery and small arms, and for blasting purposes; one of these, consisting of picrate of potash, saltpetre, chlorate of potash, and charcoal, was experimented with at Le Bouchet on a considerable scale about four years ago with some favorable results; but the experiments were abandoned in consequence of a disastrous explosion which occurred at a factory in Paris where considerable quantities of picrate of potash were stored. Much more satisfactory results have been recently obtained in this country in Government experiments with a preparation containing another salt of picric acid, the picrate of ammonia, which, by incorporation with saltpetre, furnishes one of the safest explosive mixtures of a violent character yet produced; and though it cannot compete with nitroglycerine-preparations or gun-cotton in regard to its explosive force, yet it is decidedly stronger than gunpowder. It is, moreover, of perfectly stable character, is readily manufactured in the same way as ordinary gunpowder, and its cost is moderate. It has been hitherto experimented with almost exclusively in reference to the desirability of providing the service with a shell-powder more powerful than gunpowder, and capable of sustaining the concussion of the discharges in heavy guns without the slightest risk of premature explosion. These requirements appear to be satisfactorily fulfilled by it, and a considerable quantity has recently been manufactured for the purpose of comparing it with gunpowder and other explosives as an agent for submarine operations.

Various other products of the action of nitric acid upon substances of organic origin are endowed with explosive properties, but only two of these have, up to the present time, received successful application as substitutes for gunpowder; and it is by preparations of these two substances, nitroglycerine and gun-cotton, that gunpowder has been replaced with considerable advantage in some of its important industrial applications.

Gun-cotton and nitroglycerine were discovered within two years of each other; but, while attempts were almost immediately made to apply gun-cotton to industrial purposes, its nature and the conditions essential to its successful development as a useful and reliable explosive agent being at the time very imperfectly understood, nitroglycerine was destined to remain a chemical curiosity for about sixteen years. It need scarcely be said that gun-cotton did not long maintain the advanced position into which it was forced at an early stage of its history. Disastrous accidents in England and in France, which occurred within three years of its discovery, completely destroyed the unbounded confidence too hastily placed in the mastery supposed to have been attained over its manufacture and properties; they led to its entire abandonment in England and in France for about sixteen years, and it was only in Germany that faith in its ultimate success was not altogether lost, thanks to the untiring perseverance of an Austrian artillery officer. Yet the early applications of gun-cotton, especially in England, were not without importance; the well-known gunpowder makers, Messrs. Hall, of Faversham, entered energetically upon its manufacture within a year of its discovery; its important superiority over gunpowder in many mining and blasting operations was

soon made manifest, and the demand for mining charges (consisting of gun-cotton wool tightly rammed into card-board cases) was steadily increasing, when Messrs. Hall's works were destroyed by the explosion of 1847. Numerous specimens of gun-cotton, made soon after the announcement of Schönbein's discovery, have remained quite unchanged to this day; these and portions of the products of manufacture at Faversham, some of which after having been buried since the time of the explosion, were recovered nine years ago, and are now in a perfect condition, demonstrate that even in those days stable gun-cotton was sometimes produced, and indicate that the accidents at Faversham and in France, which appear beyond doubt to have arisen from spontaneous ignition during manufacture or storage, were due rather to uncertainty in regard to the quality of the product obtained, than to an inherent instability of the properly prepared material.

It was not until 1864 that gun-cotton again began to receive attention at the hands of practical men in this country, as an explosive agent susceptible of application to industrial purposes. Its manufacture had in the meantime been carefully studied and decidedly improved by Baron von Lenk, who had also devised a system of applying gun-cotton which appeared to afford prospects of rendering it much more readily susceptible of adaptation to different purposes than the original gun-cotton wool of Schönbein. The cotton was spun into loose threads or yarn before conversion, and the finished gun-cotton yarn was either wound, or plaited, or twisted into rope, according to the purpose for which it was to be used, whether in guns, small arms, shells, or mines. Von Lenk's mining charges consisted of pieces of suitable length of a compact gun-cotton twist or rope, kept hollow in the centre, for the double purpose of receiving the fuze, and of causing the charge, when inflamed, to ignite throughout more readily than it would if quite solid, unless strongly confined. Gun-cotton in this form was made the subject of an extensive series of experiments by Baron von Ebner, of the Imperial Austrian Engineers, with the view of testing its applicability to the various military and civil mining and engineering operations to which gunpowder is applied. For blasting in hard rock, the operation being conducted just as with gunpowder, the force of gun-cotton was found to be so superior that, spite of its comparatively high price when made according to von Lenk's system, a decided saving in cost was effected. In comparatively soft rock the results, though less marked, were still advantageous, provided the rock was free from fissures; if these existed in any kind of rock, the efficiency of the gun-cotton was more or less seriously interfered with, as its full explosive force was not developed unless the material was closely confined at the moment of explosion. For submarine operations, gun-cotton in the form of rope offered decided advantages over powder, provided it was confined in strong cases, and gun-cotton was consequently adopted as the explosive agent in the submarine mines which were applied to defensive purposes by the Austrians in their last war. The absolute necessity for strong confinement of the material was, however, a serious obstacle to its ready and effective employment in open air operations, such as the destruction of stockades, or the hasty demolition of bridges, buildings, or works; for although Baron von Ebner described some successful operations in his report, the gun-cotton having been confined in cases constructed of stout wood and sheet metal, the fact that even strong receptacles of this kind could not be relied upon, to afford the initial resistance essential to the proper explosion of the gun-cotton, was demonstrated by repeated failures in the course of the demolition of works at Corfu by the Royal Engineers in 1863, when attempts were made to apply large charges of gun-cotton rope, furnished for the purpose in specially constructed cases by the Austrian Government.

The explosion, in 1862, of a magazine near Vienna, where 28 cwt. of gun-cotton were stored with a quantity of gunpowder, and one of much greater magnitude in 1865, of neither of which any satisfactory explanation was afforded, led to the abandonment of gun-cotton in Austria; but, meanwhile, experience in the manufacture of the material according to von Lenk's system, and in its application to industrial and other purposes, was being acquired in this country.

In October, 1864, at which time gun-cotton manufactured by Messrs. Prentice, of Stowmarket, was already being used to an experimental extent in some mining districts in England, the special committee appointed by Government, under the presidency of Sir Edward Sabine, to investigate

the merits of gun-cotton made and used according to the Austrian system, instituted a series of comparative experiments with gunpowder and gun-cotton in the lead mines and quarries of Mr. W. B. Beaumont, M. P., near Allenheads.* In attempting to form some estimate of the relative power and efficiency of the two explosives, the committee became strongly impressed with the great difficulty of instituting really comparative blasting and quarrying operations. In rock which appears uniform and quite sound, the blasting often brings to light veins, shakes or fissures which render a comparison of work done in two contiguous portions impossible. Even in very homogeneous hard rock, differences in structure occur which modify the resistance opposed to the explosive agent, while it is almost impossible to have two blast-holes, for comparative experiments, so placed in actual practice that their position with reference to the exposed surfaces or faces of the rock, or, in other words, the direction of least resistance, should be more than approximately alike. The results obtained at Allenheads were in most instances favorable to gun-cotton, bulk for bulk; but they varied considerably among themselves for the reasons given, and the committee could not attempt to express any decided opinion as to what might be considered the relative equivalents of gunpowder and gun-cotton used on the Austrian plan. One of the committee, Mr. Sopwith, M. Inst. C.E., whose judgment in these matters is entitled to great consideration, believed that trustworthy data regarding the relative power of different explosive agents would be best obtained by performing blasting experiments in artificially prepared homogeneous masses as closely alike as could possibly be insured; he suggested blocks of carefully prepared concrete as a suitable material. A few experiments on a comparatively small scale, which the Author executed with concrete blocks, indicated that more trustworthy results might thus be obtained than by comparing the results of ordinary blasting operations; but precise experiments in this direction have as yet been of a limited character.

One decided advantage which gun-cotton was found to possess as a blasting agent, in the experiments of the committee, and which was confirmed by practical experience in underground work, was the absence of smoke; the miners were enabled to return to their work in a much shorter time after a blast with gun-cotton than when powder was used; but this was not the case if the rock operated upon was unsound, or if the resistance opposed to the gun-cotton was insufficient to develop its full explosive force; the incomplete explosion of gun-cotton being attended by the development of vapors of an irritating character, which could not be inspired without much inconvenience. An important objection to the Austrian mining charges of gun-cotton rope was the comparatively loose condition, or the want of rigidity, of the material, which caused it to be easily altered in shape (or upset) if any force were used in pushing a somewhat tightly-fitting charge down a hole; if an attempt was then made to drive home the charge it became tightly jammed, and several accidents occurred in consequence of the explosion of charges of gun-cotton-rope by the great friction to which portions were exposed in the violent treatment adopted by the miners in driving a jammed charge home.

Some little advantage was derived with the gun-cotton-rope charges from an increase in the amount of tamping which could be introduced into holes of a given length, owing to some reduction in the length of charge required as compared with powder; but the gain in this direction was greatly increased when the Austrian form of charge was replaced by compressed gun-cotton in 1868. The density of the former was =about 30 lbs. per cubic foot, while that of the latter was about 60 lbs.; this, and the difference in the form of the charges, caused the compressed gun-cotton to occupy somewhat less than half the space of the rope-charges; hence the blast-holes could be reduced in length and diameter, or a considerably larger amount of tamping could be used; or, if necessary, a large charge of gun-cotton could be employed in any one operation. The smooth and hard exterior of the cylindrical charges of compressed gun-cotton rendered the operation of loading with them comparatively easy, and it was only in rugged and uneven holes that there was a liability of the charge to become jammed. Accidental ignitions and explosions have, however, occurred with compressed gun-cotton, in consequence of the great amount of violence used in forcing or

* Reports relative to the application of gun-cotton to mining and quarrying operations, printed for the House of Commons, April, 1869.

driving home the charge. If it should happen to be ignited by powerful friction just as the force of a blow is spent and the jumper or driving-rod is being withdrawn, it will simply burn, but if the ignition takes place while the implement is pressing upon the charge, the full force of the operator being perhaps applied at the moment, the conditions are obviously the same as though the gun-cotton were firmly tamped, and a violent explosion must result. It is a question, however, whether, if wooden tamping-rods had been used in the place of metal tools, the accidents which have occurred in charging holes with gun-cotton might not have been in a great measure avoided. In addition to the advantages which have been pointed out as resulting from the production of compressed gun-cotton, there are some others which have a direct bearing upon its application to industrial purposes. The employment of cotton waste in its production, in place of long staple cotton of high quality, which was required in the manufacture of the Austrian gun-cotton, and the important saving of time effected in the manufacture of mining charges, have led to a considerable cheapening of the material. The incorporation of at least ten hundred weight of gun-cotton at one time, in the purifying process which it undergoes after reduction to pulp, and before it is pressed into charges, gives rise to far greater uniformity than could possibly be attained, even with the most extreme care, when the products of separate small operations of manufacture were directly converted into charges. The circumstance that the compressed charges do not burn with the explosive violence exhibited by spun gun-cotton, even if they are confined in the packing-cases ordinarily used, renders the material much safer to store and handle, and has reduced considerably the chances of explosions resulting from the accidental ignition of the material during transport and in store. An additional and important element of safety arises from the superior efficiency of the purifying treatment to which the gun-cotton is subjected in the finely-divided form, as compared with the old system of washing the long fibres of gun-cotton.

One of the chief advantages of compressed gun-cotton consists in the convenient and safe form in which the charges are furnished to the miners, who carry them about and handle them without fear or risk of accident; unfortunately, this advantage cannot but constitute occasionally an indirect source of danger, as an overconfidence in the safety of the material will lead the miner to forget at times that he is dealing with an explosive agent, and hence he will occasionally perform reckless acts in charging the blast holes, which must inevitably result in disaster.

One or two other special advantages have resulted from the conversion of gun-cotton into homogeneous compressed masses, but these will be dealt with more appropriately when the methods of applying the companion explosive agent, nitroglycerine, have been examined into.

Nitroglycerine has been raised from the position which, as already stated, it held for sixteen years as a rare and apparently useless chemical product to that of a most important chemical industrial agent, entirely through the skill, ingenuity, and perseverance of Mr. Alfred Nobel. While repeated efforts were made to utilize gun-cotton and to perfect its manufacture, nitroglycerine continued to be regarded by chemists as akin to the chloride of nitrogen with respect to its uncontrollably dangerous character and its instability, and as being utterly unsusceptible of practical application, partly on account of the difficulty of bringing about its explosion by practicable methods, and partly on account of the great danger supposed to attend its manufacture and all manipulations connected with it.

At about the time when the Austrian improvements in the application of gun-cotton began to receive attention in England, Mr. Nobel made public his first attempts to apply nitroglycerine to practical purposes. In 1863 he proposed to add to the explosive power of gunpowder used in the ordinary way by impregnating the grains with nitroglycerine. This proposal was speedily followed by Mr. Nobel's discovery of a satisfactory method of developing the explosive force of nitroglycerine, either in its pure state or in admixture with other substances. The fact that nitroglycerine and analogous bodies are only slowly burned or gradually decomposed when brought into contact with an ignited body in the open air, unlike gunpowder and other explosive mixtures, led Mr. Nobel to conclude that it was necessary, in order to determine their explosion, to raise them, or some portion of them, rapidly to the temperature at which

that result would be produced, and that if only a small portion were thus heated to the exploding point the explosion of the entire mass would be brought about. In 1864 Mr. Nobel described several methods for raising portions of a charge of nitroglycerine to the temperature necessary for developing what he termed the initiative explosion; of these the really efficient one consisted in exploding a large percussion cap in contact with, or in close proximity to, the charge of nitroglycerine. It was found that the explosive metamorphosis proceeds with such almost instantaneous rapidity throughout the mass, from the portion in immediate proximity to the initiative agent, that confinement by tamping or other means is not required for the full development of the explosive force of nitroglycerine. The Author was led in 1867-8 to examine into the general question of the conditions which determine and regulate the explosion of compounds and mixtures, and did not find that Mr. Nobel's explanation of the development of detonation furnished a sufficiently satisfactory solution of many results obtained with nitroglycerine and other explosive agents; but there is no question that Mr. Nobel was the first to apply an initiative explosion or detonation to the ready development of explosive force from substances which otherwise will not readily operate explosively, and that he was also the first to succeed in applying a liquid explosive agent to practical purposes.

While a mode of applying nitroglycerine was thus being established by Mr. Nobel, he also developed the manufacture and purification of the material to so great an extent that the grave doubts entertained within a recent period regarding the possibility of regularly producing it in a condition of purity and stability, which were fully warranted by the previous experience of chemists, have already given place to considerable confidence in the keeping properties of the substance.

Nitroglycerine in its pure or undiluted condition was soon demonstrated to be the most powerful explosive agent yet made known. The economy in time and labor effected by its use in blasting and tunnelling in hard rock is undoubtedly greater, under favorable circumstances, than with gun-cotton or any of the most powerful substitutes for gunpowder. Moreover, the liquid form, high specific gravity, and insolubility in water of nitroglycerine, are peculiarly valuable properties under some circumstances; thus, blasting in wet holes, or actually under water, can be carried on with nitroglycerine expeditiously and without any special appliances. The efficiency of nitroglycerine as a mining agent having been established in Sweden and in Germany, demands soon arose for the material in other countries, and it has been extensively employed in mining districts abroad especially in California. In Wales it was used by some quarry-owners as a most efficient agent for tunnelling and for removing the hard rock overlying the slate; but the liquid nature of the material, and one or two of its other properties, were soon found to constitute important sources of inconvenience and danger.

The poisonous nature of nitroglycerine, which injuriously affects the health of those handling and using it, is one of its defects. It is stated, however, that the human system may become accustomed to its influence, so that after a time the prejudicial effects on health, or the inconvenience attending the employment of nitroglycerine and its preparations, diminish or subside altogether. At any rate, there is no doubt that miners would not be deterred by these defects from availing themselves of the advantages presented by a powerful and efficient blasting agent. The comparatively high temperature at which nitroglycerine freezes, and the slowness with which it thaws, even at a normal atmospheric temperature, constitute a source of inconvenience, and, in some respects, of danger, though not perhaps in the particular direction in which many who have devoted attention to these subjects at first believed. The facility and violence with which a solid explosive agent will undergo detonation, when exposed to the operation of mechanical force, are in inverse proportion to the readiness with which the particles of the mass can yield to, or be moved by, the blow applied; thus, a highly-compressed mass of a fulminate-mixture can be exploded by a much lighter blow than a portion of the same mixture in the state of powder, because, in the latter case, the force of the blow is partly expended in mechanical work upon the loose particles of the mass struck. Similarly, therefore, it was believed that the yielding or mobile condition of the particles of a liquid must render it less susceptible to explosion by a blow or violent concussion than the same

material in a solid condition. This view appeared, in the instance of nitroglycerine, to be supported by some fearful accidents which occurred in Sweden and in this country during the handling of frozen nitroglycerine. It has, however, been established beyond all doubt, that the material is much less susceptible to detonation in the frozen than in the liquid condition; the comparative inertness of the frozen substance constituting in fact, occasionally, a source of considerable inconvenience. In considering the behavior of the substance when subjected, in the different physical conditions, to heat suddenly applied through the agency of friction or a blow, the fact was overlooked that the transformation of the liquid into gas must involve much less expenditure of heat than the same transformation of the solid, or frozen body; a circumstance to which the inferior sensitiveness of the latter to detonation must be, at any rate, mainly ascribed. The accidents which occurred with frozen nitroglycerine appear to have arisen from a recklessly rough usage of the material; and, so far as the apparently great safety or inertness of the frozen substance will lead to occasional recklessness, it does constitute a source of danger. The necessity for thawing the nitroglycerine (and its preparations) for use, unless exploding arrangements of a special character be provided, has also proved to be a source of accident; for though simple and safe regulations for thawing have been laid down and prominently insisted upon, it is impossible to guard against occasional mistakes, or against the deliberate thoughtlessness which is so fruitful of casualties with gunpowder in the mining districts, and is aptly illustrated by the recent well-authenticated case of a man who, desiring to tap a powder-barrel, and being unable to find his auger, proceded to bore a hole in the heart of the cask with the read-hot poker.

The principal defect of nitroglycerine, when employed in its pure state as a blasting material, arises, however, from its liquid nature, and its consequent tendency to leak out of receptacles in which it is transported, stored, or used. In blasting operations, the nitroglycerine with which a hole is charged will flow into fissures in the rock, and may thus be conveyed to parts where its existence cannot be suspected, and where it may be afterwards accidentally exploded during the boring of other holes. Numerous more or less terrible nitroglycerine explosions have occurred in different parts of the world, the majority of which are considered to have been primarily due to the leakage of nitroglycerine from the packages in which it was transported and stored, notwithstanding the care with which these were constructed and packed. The great susceptibility of nitroglycerine in the liquid form to detonation, especially during hot weather or in tropical climates, would lead to the explosion of portions of the liquid which had escaped from the packages by accidental concussion or comparatively slight blows, and thus disastrous explosions would be brought about. In order to reduce the chances of accident, Mr. Nobel adopted the ingenious precaution of dissolving nitroglycerine in wood spirit, and diluting it with that solvent sufficiently to render the mixture quite non-explosive, the oil being easily separated, when required, by simple addition of water. But this precautionary measure was only partially successful, because the vapor of the highly volatile wood spirit readily escaped from minute imperfections in the packages, and, as the spirit became weaker, an explosive mixture of nitroglycerine with a small proportion of spirit collected at the bottom of the vessel, the material thus being restored to a dangerous condition.

In the course of Mr. Nobel's persevering endeavors to counteract or reduce the sources of danger attending the use of nitroglycerine, he made the most important observation, that the readiness or certainty with which it is exploded through the agency of a detonation is not reduced, but, on the contrary, somewhat favored, by mixing the liquid with solid substances, in themselves thoroughly inert. This discovery led at once to the production by Nobel of solid, or more or less pasty, preparations of nitroglycerine, which, under the name of dynamite, were first brought before the public in 1867, and the most perfect of which constitutes, as now manufactured, one of the safest, most powerful and most convenient explosive agents applicable to industrial purposes. By the absorption of nitroglycerine by porous solids, or its mixture with non-absorbent solid bodies in a fine state of division, that substance is presented in a condition in which it may be manipulated like any solid explosive substance, with the additional advantage of plasticity; and if such a preparation is made

according to the system now pursued by Nobel, it appears to set aside completely, or nearly so, all objections to nitroglycerine which could arise out of its liquid form. It is true that by diluting nitroglycerine with non-explosive substances, or even with other less powerful explosive materials, the force available from a given weight of substance becomes diminished; but the power of pure nitroglycerine is so much greater than that of gunpowder, that it will bear considerable dilution without important detriment to the high position which it holds among powerful agents.

The form in which dynamite was first presented to the public and the only form in which the author had seen it before 1870, was that of a loose, soft, readily mouldable powder of a pink or buff color, which consisted of about 75 parts of nitroglycerine held absorbed by 25 parts of a porous, infusorial, silicious earth, known in German as "kieselguhr." The moist appearance of this powder favored the opinion that the nitroglycerine would be liable to exude from it, or concentrate itself at the base of a package during transport or long-continued storage. The dynamite, as thus supplied, was made up into cartridges by the miners, an operation which was attended with inconvenience on account of the absorption of nitroglycerine by the hands, and its consequent unpleasant effects upon the system. For some time past, however, dynamite has been furnished to the trade in the form of small cylindrical cartridges, consisting of the material in a compact condition, enclosed in a single wrapping of parchment paper. These cartridges are consolidated by pressure, whereby any excess of nitroglycerine which the porous earth will not hold absorbed is expelled, and thus the separation of nitroglycerine during handling, transport, or exposure to elevated temperatures, appears effectually guarded against. The consistency of the dynamite charges is like that of dry putty, and the fingers are scarcely soiled with nitroglycerine when the uncovered charges are handled.

The kieselguhr selected as the medium for the application of nitroglycerine appears the material best calculated to hold absorbed a large proportion of the liquid, and to retain it even when the mixture is submitted to considerable pressure. When dynamite factories were established in the outskirts of Paris during the late siege, and this particular silicious earth could not be procured, a series of experiments was instituted for the purpose of discovering a good substitute; the most efficient absorbents next to this material were found to be precipitated silica, kaolin, tripoli, precipitated alumina and sugar; but none of these appeared thoroughly equal to kieselguhr in their power of retaining a very large proportion of the oil.* Indeed, no other preparation has hitherto been proposed containing so large a proportion of nitroglycerine so safely applied as Mr. Nobel's so-called No. 1 dynamite. Another form, known as No. 2, and containing a much smaller proportion of nitroglycerine, mixed with finely powdered saltpetre and resin, or coal, is manufactured by Mr. Nobel as a cheaper blasting agent, for employment when the violent crushing and rending action of the stronger dynamite is not required.

Since the idea of incorporating nitroglycerine with solid substances was first conceived by Nobel, several preparations of that substance have been devised, in all of which the porous silica has been partly or entirely replaced by solid substances of an explosive or semi-explosive character. Among these, the following may be named as having received some amount of practical application: Colonia powder, which consists of a modified gunpowder, saturated with nitroglycerine, and is therefore very similar to the first nitroglycerine preparation devised by Nobel; Horsley's blasting powder, which consists of the chlorate of potash and nut-gall powder impregnated with 20 per cent. of nitroglycerine; Dualine, which may be described as Schultze's sawdust powder impregnated with nitroglycerine; Glyoxiline, which consists of a mixture of gun-cotton pulp and saltpetre, converted into porous pellets, which are saturated with nitroglycerine, and afterwards coated with varnish or other protective materials; and Lithofracteur, in which the silicious earth and nitroglycerine of Nobel's dynamite are partly replaced by semi-explosive material, *i.e.*, by substances which fulfil the part of the gunpowder in colonia powder, or of the charcoal and saltpetre in Nobel's No. 2 dynamite. It need scarcely be said that all these preparations partake of the properties of the original dynamite, though they differ considerably in their nature.

* The ashes of Boghead coal were eventually used for the production of dynamite during the siege, as the best substitute for kieselguhr.

The first four consist entirely of explosive materials; of these, Horsley's powder and glyoxiline probably approach most nearly to dynamite in their explosive power.

The preparation called Lithofracteur, for which considerable publicity has been obtained during the last twelve months, is stated to be a secret composition, at any rate in the form now introduced into this country. Some information as to its nature was, however, made public previously to its being brought forward in this country by the agents of Messrs. Krebs, of Cologne. In an interesting work by Lieutenant Trauzl, Imperial Austrian Engineers, on the application of dynamite and gun-cotton, in which a decided preference is given to dynamite in most particulars as an explosive agent for industrial purposes, the chief defects of this material are stated to be the ready separation from it of nitroglycerine when in contact with water, and its tendency to freeze at comparatively high temperatures. It is pointed out that these defects are of minor consequence in the ordinary applications of the substance, but that they are of more importance in connection with large submarine operations and with its application to war purposes. Lieutenant Trauzl further states that neither of the defects is overcome in the two other nitroglycerine-preparations then known in Germany, namely, dualine and lithofracteur. He describes the latter as being simply dynamite, in which an imperfect kind of gunpowder has been substituted for a proportion of the silicious earth, and gives the following as the approximate percentage composition of the material: nitroglycerine, 52; silicious earth and sand, 30; powdered coal, 12; nitrate of soda, 4; and sulphur, 2. Lieutenant Trauzl, when he visited this country in 1869, gave the Author a sample of lithofracteur which had been furnished him by Prussian officers; this was found to contain the substances above named in somewhat different proportions, and with the addition of a small quantity of sawdust. It is of course possible that the composition of lithofracteur may have since been again modified, and that the substance which has been used in experiments in the Nantmawr and Breidden quarries within the past year differs in some respects from the specimens about which there was no secrecy; but it has been publicly acknowledged by the manufacturers that the material is a modified dynamite, for which, however, special merits, in regard to power and safety, are claimed. With respect to power, it is difficult to conceive that a considerable proportion of the nitroglycerine contained in dynamite can be advantageously replaced by a crude explosive mixture, which cannot but be less powerful in its action than that liquid; with regard to safety, it is obvious that the ready susceptibility of a particular nitroglycerine-preparation to explosion by blows or concussion is likely to be in direct proportion to the amount of nitroglycerine which it contains. The experiments made near Shrewsbury, in May, 1871, with lithofracteur, afforded satisfactory evidence of the safety of this material in transport, under circumstances likely to occur in practice, and a decided opinion to that effect was officially recorded by the Author at the time. Those results appear to have been fully confirmed by experiments recently carried out at Nantmawr in the presence of a Government committee. At present, however, there is no evidence that Nobel's dynamite would not successfully withstand similar practical tests to those carried out with lithofracteur; and, judging by the specimen of that substance handed to him by Leutenant Trauzl, the Author believes that, at any rate in one respect, namely, the retention of the nitroglycerine at different temperatures, and under some conditions of transport, storage, and use, Nobel's dynamite possesses a decided superiority over lithofracteur. Actual practice on an extensive scale can, however, alone determine satisfactorily the relative value of these nitroglycerine-preparations.

In discussing the merits, as a mining and blasting agent, of gun-cotton in its most recent and compressed form, the employment of this material was considered in an earlier part of this Paper under precisely the same conditions as are fulfilled in the employment of powder. Compressed gun-cotton was, however, found by Mr. E. O. Brown, in 1868, to be susceptible of violent explosion through the agency of a detonation, like nitroglycerine and its preparations, one point of difference being that a more powerful and sharper detonation is required in the case of gun-cotton. When employed in the compressed form in this manner, gun-cotton becomes analogous in its behavior and effects as an explosive agent to nitroglycerine; but the latter, in its pure condition, still appears to remain the more violent explosive substance. In

ordinary blasting and quarrying operations where small charges are employed, the detonation of gun-cotton does not appear to present decided advantage over its explosion in the ordinary way, except in so far that hard tamping may be dispensed with, and that unsound holes may be successfully blown by detonation, while gun-cotton otherwise applied would probably fail in them. But in the employment of large charges, in submarine operations, in works of demolition, and others of a military class, the explosion of gun-cotton by detonation presents important advantages, because its strong confinement may be entirely dispensed with, and, as in the case of nitroglycerine and its preparations, with some waste of power it may readily be made to operate most destructively without any confinement whatever. Thus, the rapid destruction of works and buildings, of stockades or bridges, the disintegration of boulders or other large masses of rock, the breaking-up of guns and other masses of metals, may be alike expeditiously accomplished by compressed gun-cotton and by nitroglycerine, dyamite, and similar preparations, the charges being either completely unconfined, or introduced into perforations which may be left open.

It may be expected that some definite statement should be given of the comparative effects, as mining and blasting agents, of gunpowder and of the violent explosive materials which have been more especially referred to. Excluding nitroglycerine in its pure or liquid form as pre-eminently dangerous, and therefore only likely to receive exceptional application, and taking dynamite and compressed gun-cotton as fairly representing the really useful explosive agents of the violent class, it may be stated, generally, that in all operations where rapid destruction is to be accomplished, as in the instances just referred to, gunpowder is incontestably inferior to those explosive agents. Not only would a much larger quantity of powder be required to produce similar results, but in some instances, it would be impossible to perform the same operations even with exorbitantly large charges of powder. This is especially the case in the breaking up of masses of hard rock or metal by the superposition, or simple insertion into cavities, of the explosive agent. Again, in tunnelling and blasting in hard rock, the new explosive agents represented by dynamite and gun-cotton possess undoubted advantages. Important economy is effected by their use, not simply in regard to cost of material to produce equal effects, but in regard to saving of labor, of tools, and of time. Short charges and long tamping (which need not be hard tamping) insure the breaking up of the hole to the bottom, and generally tend to break up the rock beyond the bottom of the hole. The holes may be of smaller diameter, and are more rapidly loaded; the latter being especially the case with holes which are horizontal or driven at an upward angle.

Practical experience with compressed gun-cotton in North Wales, which no doubt also bears upon the employment of dynamite, has shown that in tunnelling in the slate qurrries, where sixty shillings per yard has to be paid when gunpowder is used, the same quantity of work can be done, and in less time, for forty-five shillings per yard.

The shattering and splitting effect of dynamite and gun-cotton in hard rock is much greater than with powder, but, in quarrying, the rock is generally not thrown off by them to the same extent. It is frequently found advantageous, in rapid working, to drive large and deep holes far back from the face, and charge these with the violent explosive, by which the rock is extensively fissured; large quantities of powder are then poured into the fissures, and by its explosion enormous quantities of rock are removed. In submarine blasting, a similar mode of combining the shattering and displacing effects of the violent and gradual explosive agents have been found very advantageous. In submarine demolitions, as in the destruction of wrecks, the violent explosives generally have a decided advantage; but in some operations upon iron ships, it has been found that the lifting effect of large charges of powder is advantageous in clearing away framework and other parts which have been shattered, but not actually removed, by the more violent explosive agents.

When a moderate cleaving and separating effect is required, accompanied by as little local action as possible, gunpowder cannot at present be advantageously replaced; as, for example, in the raising of large blocks of the finest slate. In other instances, of less frequent occurrence in industrial works, but which may be of some importance in military operations

where great displacing action is required, gunpowder has the undoubted advantage. In the submarine blasting of very soft rock, such as soft limestone or chalk rock, the comparatively instantaneous action of the violent explosives operates disadvantageously in regard to their displacing power. As an illustration of this, some experiments made under Mr. Hawkshaw's direction in June, 1870, upon the foreshore near the Shakespeare tunnel, at Dover, may be referred to. The object was to ascertain whether the detonation of gun-cotton charges, placed upon the surfaces of submerged soft chalk rock, would break up the latter to such an extent as to facilitate its rapid removal by dredging. The results showed that the rock was completely disintegrated, or pounded into a plastic mass like clay, within a comparatively limited area; but that the shattering or rending of the rock did not extend to any considerable distance, as it would have done in the case of hard rock, of which the portions contiguous to the charge would have presented greater resistance to the blow exerted by the extremely rapid explosion. Numerous experiments made in this and other countries with gun-cotton and dynamite have shown that the violence of the concussion due to the suddenness of the explosion gives materials of this class important advantages over gunpowder for use in submarine mines.

Though it may be comparatively easy to point out, generally, the peculiar practical advantages which these violent explosive agents possess over gunpowder, it is exceedingly difficult, indeed impossible, in the existing state of knowledge, to give any precise information as to the equivalents of such materials as dynamite, gunpowder, gun-cotton, etc., or to state, even in regard to special applications, how much of the stronger explosive is really equivalent to a given weight of gunpowder or of some other material. Such statements are, however, constantly made, and with great confidence; thus the Author has even heard a particular nitroglycerine-preparation spoken of as having, in some rough experiments, produced a result ten per cent. better than that of another similar preparation. The serious difficulties have already been referred to which attend any attempts to institute a strict comparison between the destructive effects of different explosive agents, and there can be no doubt that, at any rate at present, long-continual use of two materials in the same class of work can alone determine their relative merits by the average results furnished. With regard to dynamite (which it is presumed may be considered certainly not inferior to lithofracteur) and compressed gun-cotton, it may be stated generally, but with reserve, that in ordinary blasting operations, the results furnished by them, weight for weight, are accepted as being about six times those produced by gunpowder. In comparing the effects of dynamite containing 75 per cent. of nitroglycerine with those of gun-cotton, the two materials appear to be practically on an equality as regards power, weight for weight; but dynamite has this advantage, which is shared by similar preparations, that, in rugged and uneven holes, a somewhat larger charge can be introduced into a given length of hole, because its plasticity permits of its being made by gentle pressure to completely fill the space allotted to the charge, while the rigid gun-cotton will not accomodate itself to irregularities in the shape of the hole. With regard to other special advantages of either of the explosives named, the most prominent one of dynamite is, that it may be used in a damp hole without fear of its missing fire; while, on the other hand, compressed gun-cotton possesses the advantages that it is not in any way injurious to handle, is not at all affected, in its ready explosiveness, by cold, and may, if necessary, be preserved for any length of time, without deterioration, in the damp and perfectly unignitable state. With regard to the vapors evolved by the two materials in underground work, there is no question that both possess the advantage over gunpowder, and explosive mixtures analogous to it, of producing but little smoke; but if a hole should be overcharged, or if the explosion should be imperfect from any cause, then the vapors evolved in both instances are decidedly more objectionable than gunpowder smoke.

In discussing the improvements which have of late years been effected in the production and application of explosive agents other than gunpowder, one cannot but be impressed with the great advance which has been made in a knowledge of the properties of some of these important industrial agents. The remarkable development which has taken place in the application of nitroglycerine affords a striking illustration of the manner in which chemi-

cal products, regarded for years as scientific curiosities, may start into importance; and encourages the belief that other organic derivatives, which are at present known but to few, as substances endowed with remarkable explosive properties, may yet become important rivals of gun-cotton and nitroglycerine. Some interesting results recently obtained by Dr. Sprengel indicate that new fields are possibly opening up already for the industrial application of compounds or mixtures not hitherto used as explosive agents. Dr. Sprengel has observed that mixtures of strong nitric acid with solid or liquid substances having a great tendency to combine energetically with oxygen, can be made to explode through the agency of a detonation, some of them producing violently destructive effects. He also finds that mixtures of readily oxidizable liquids with solid oxidizers, such as chlorate of potash, are similarly explosive. Thus, mixtures of bisulphide of carbon and chlorate of potash, of picric acid and of nitrobenzol with concentrated nitric acid, furnish powerfully explosive preparations, susceptible of detonation. It remains to be seen whether mixtures of this class can be applied with advantage as substitutes for the violent explosive agents which are now rapidly supplanting gunpowder in some of its important uses.

Even gunpowder can, however, be said not to have remained entirely passive in the general development which has recently taken place in the industrial application of explosive agents. Among the results of the experimental inquiry which the Author instituted four years ago, with the view of throwing light upon the nature and cause of the phenomena exhibited by nitroglycerine and gun-cotton, when submitted to the action of a detonation, was the observation that all explosive compounds and mixtures, even including gunpowder, are susceptible of violent explosion through the agency of a detonation, though the nature and force of the required detonation vary considerably with different explosive substances. It was found that the full explosive force of gunpowder could be developed without a close confinement of the charge, by the employment of a sufficiently powerful detonating fuze; and a series of experiments, instituted during the demolition of works by the Royal Engineers at Chatham and at Portsmouth, indicated that decided advantages were attained by employing detonating fuzes for the explosion of charges of gunpowder which were not strongly confined. In submarine operations, the advantage of using a detonating fuze with gunpowder has been even more manifest, it being decisively proved that by their use that the full explosive force of a large charge of powder could be developed without employing the very strong receptacles required for insuring its complete ignition when fired in the ordinary way.

Some interesting results were also obtained in blasting experiments with gunpowder in which the charge was ignited at different distances from the top, and which indicated that, in blast-holes of considerable depth, decided advantage was gained by igniting the charge at or near the base, as the upper part then acted as additional tamping to the portion first ignited, and thus considerably increased the violence of the explosion. These few points are briefly referred to with the object of indicating that it is not only in the application of substitutes for gunpowder that much has yet to be learnt, but that the whole subject of the application of explosive agents, generally, to industrial purposes is still a most fruitful one for patient investigation.

HIGH PRESSURE HYDRAULIC ENGINES.

By ARTHUR RIGG.

From "Iron."

The earlier hydraulic engines intended to give uniform rotary motion were not very successful, and it was not until the subject was taken up by Sir William Armstrong, who is the pioneer in the practical development of so much hydraulic machinery, that an engine of this class became available for general use. An important point gained by his hydraulic engine was the removal of destructive shocks which had hitherto taken place when turning centres, and this was accomplished partly by the arrangement of the engine, and partly by relief valves. Instead of admitting water alternately on

both sides of the piston, like a steam engine, the piston is made twice as large as the rod, and pressure kept constantly on the upper side, or annular space forming half the area, while being admitted and exhausted alternately to the lower side by a slide valve. This plan does away with shocks on the upper side of the piston, but a more ingenious arrangement removed them from the lower side. Relief valves were placed between the cylinder and inlet, leading out of the former into the latter, so that any accidental access of pressure might find an immediate vent, and though it seems wrong to remove the effect of an evil, without touching on its primary cause, yet this arrangement has been found to be practically perfect in its action.

These shocks indicate an imperfect valve-setting—by too sudden admission of water; and when it is remembered how mischievous this effect is found to be even with so elastic a fluid as steam, it is evidently much more destructive with water, especially when under pressures of from 700 to 1,000 lbs. per square inch. It may be proved that this cause is the true one, for if an ordinary hydraulic engine have a minute lead by cutting a small orifice in the valve, and be driven at a slow speed, there will be no shocks even without relief valves. Still they are most desirable additional safeguards, for neither durability of original arrangements nor perfection of workmanship are things to be relied upon.

Good as were these earlier improvements upon the old idea of an hydraulic engine, fashioned generally as a steam engine, yet it was necessary to abandon the single cylinder and substitute a pair with their cranks at right angles to each other, and a fly-wheel between them. The well-known irregularity of driving power due to this system became singularly conspicuous in such an engine, and so great a speed is necessary to secure a good result as to be rather fatal to the smoothness of motion, and very little experience leads to the present usual arrangement of three cylinders, generally made oscillating, with their cranks at 120 deg. to each other.

These engines work very satisfactorily, and the labor and ingenuity spent in their design and construction form not the least of the many sevices which Sir William Armstrong and his partner, Mr. Westmacott, have rendered to the cause of hydraulic engineering.

But an examination and consideration shows more yet left to be done; not so much in obtaining a better practical result, as in making the machine cheaper, and less complicated. In fact the system is nothing else than three separate complete engines, each contrived to make amends for the defects of the others, and so secure a tangential driving power, or a power equal through equal arcs of the crank's path, sufficiently accurate for all practical purposes, though not theoretically correct.

Slide valves are generally used, but even when made of the hardest available metal, they are liable to wear; and this evil is sufficiently objectionable when an engine has only one valve, but it is considerably worse when there are three. The cause of wear is not very difficult to discover, and a short investigation of it suggests a remedy.

These engines generally work at pressures of from 700 to 1,000 lbs. per sq. in., exerted, of course, on the whole of the back of the slide-valve, or an area of about 3 sq. in. Thus at a working pressure of 800 lbs. per square inch, there will be 2,400 lbs. pressure on the back of the slide-valve, as it travels, and borne by its edges only, which are 2 sq. in. area.

It is easy to see that $\frac{2400}{2} = 1{,}200$ lbs. per square inch is what the rubbing surface has to resist, and this is more than any metal in general use can bear without abrasion. Hence these valves wear away rapidly, independently of consuming much power to work them. Arrangements for balancing the pressures are good, but the wear may be obviated to a great extent by increasing the surfaces exposed to friction, and admitting a film of high-pressure water underneath, so that the enlarged surface gives no additional strain; and this plan, being simple and readily adopted, is used in the engine above illustrated, instead of more complicated balancing arrangements.

The construction of cylinder and valves is generally similar to that of hydraulic engines now in use, except that the former is fixed instead of oscillating, but either arrangement works well. Nevertheless, a fixed cylinder avoids the necessity for several joints, which are apt to be troublesome; and is preferable on the whole. The piston-rod is 2 in. diameter, and the piston nearly $2\frac{1}{8}$ in.; their respective areas being exactly as 1 in 2. Pressure is always on the upper side while working, but alternately on the

lower side, admitted and exhausted by the slide valve.

This valve is worked from an ordinary eccentric; and it possesses neither lap nor lead except to the small extent previously mentioned. During the down-stroke the lower side of the piston remains open to the exhaust, while the annular space between the piston and rod on the upper side has a constant pressure upon it, which impels the piston downwards. During the up-stroke pressure is admitted below the piston, but acts only on the area of the rod; being balanced by an equal and opposite pressure so far as the difference between the areas of piston and rod are concerned; and though the exhaust is an intermittent stream, occurring only during the down-stroke, yet the inlet and working of the engine are performed by equal quantities of water during both up and down stroke; and thus it becomes double acting. The arrangement of crank, eccentric, connecting-rod and slipper, guide, etc, need not be farther described, as they are obvious from the drawings, and closely resemble the corresponding parts in a steam engine.

Having described the essentials of all hydraulic engines, it becomes now necessary to consider those special peculiarities of this one, whereby an uniform reciprocating motion is transformed into a uniform rotation, and compensation provided for the well-known irregular action of cranks. This is done by the cam, roller, and plunger.

On the main shaft there is a cam of peculiar shape, with a roller attached to the head of a plunger which works in a small cylinder communicating with high-pressure water. For convenience this plunger is made 2 in. diameter, like the piston-rod, and therefore forces the roller it carries against the cam with a constant pressure equal to that of the main piston or rod.

As a mathematical investigation of the combined effects of the crank and connecting rod becomes complicated, and the simpler plan of geometrical construction gives sufficiently accurate results for any practical purpose, and is of more interest to the general reader, it has been adopted in the following considerations. The cylinder or piston-pressures may be taken in hydraulic engines to be constant and uniform throughout its course; but when converted into tangential pressures round the orbit of the crank, they vary from zero at the dead-centres, to a maximum at nearly the centre of the stroke. This variation is exactly proportional to the piston stroke, during any two corresponding equal arcs, and, for example, if the semicircles be divided into 12 equal arcs of 15 deg. each, and the piston stroke be also divided into 12 equal parts, or $\frac{3}{4}$ of an inch each part; then in order that the tangential pressures on the crank shall be equal, it is only necessary to insure that each of the 12 arcs shall receive the effect of a piston motion of $\frac{3}{4}$ of an inch, and this is done by the compensating action of the cam and its arrangements.

If a diagram be made of the up-stroke, it will show that the piston moves 3-16ths of an inch during the first 15 deg. of the crank, and 17-32ds and 27-32ds of an inch and 1 inch respectively during the succeeding equal arcs. Now, if the cam be made of such a shape as to add 9-16ths to the first, 7-32ds to the second, and to deduct 3-32ds from the third, and $\frac{1}{4}$ from the fourth arc, etc., etc., it will be found that the combined movements of the main piston and the cam piston taken together, invariably provide a motion of $\frac{3}{4}$ of an inch through all equal arcs of the crank's path, and as the end of every revolution, the amount added is always exactly equal to that deducted, no loss of power whatever occurs by the process, though, of course, a trifling loss is due to friction.

A similar arrangement equalizes the down stroke, and thus a perfectly uniform circular motion is secured with mechanism exceedingly simple and effective. The rolling contact produces no wear, and the moving parts are all of large size and substantial proportions.

These engines can be placed away in any positions, and worked by a stop-valve from a distance; and they possess the unfailing advantage of starting from any point where left standing. They are compactly arranged on a strong cast-iron bed-plate, and it has been found in practice that no noise is produced by the cam and roller, while the working of the whole is perfectly smooth and noiseless.

With this, as with all other hydraulic engines, a slow movement is found most conducive to a high duty, and it is desirable that the work to be done by them should be tolerably uniform in character. In order to provide for those few cases where variable power is required, a peculiar form of

centrifugal governor has been arranged applicable to a modification of this engine, and it alters the length of stroke, thereby affecting the cylinder capacity; but, as a rule, it will be found better to suffer an occasional loss of power rather than to complicate machinery in those cases where hydraulic engines are not used for those duties for which experience proves them to be most suitable.

LIGHTNING CONDUCTORS.

From "Engineering."

About a century has elapsed since the first practical idea of a lightning conductor was suggested. Of recent years their value has been more or less appreciated, but, with the exception of their application to the preservation of shipping, little has been done in the extension of their use. Where employed they may be or are considered much in the light of a talisman. This remark, of course, applies to erections on land, in which, as we shall subsequently show, little or no heed has been paid to the teachings of science. For all practical purposes we may consider the lightning conductors of the present day, on land, as simple invitations of electricity to spread evil. Perhaps this idea has prevailed largely among architects, and has so prevented their more frequent use. We have made it a matter of remark in tours in all parts of the kingdom during the last two years, that not one tall erection (such as a factory chimney or church steeple) in a hundred, is so protected. Suggesting to the manager of a large public company, during the erection of a chimney about 180 ft. high, the desirability of a lightning conductor, he replied that a neighboring shaft had not been "struck," during the last thirty years, and therefore he could not see the necessity.

Theoretically, almost every ordinary house should be safe from much danger; but experience proves this not to be the fact. The roofs of most houses have either lead or zinc for gutter purposes. Attached, or nearly so, to this, is the iron or zinc pipe which conveys the rain water to the drain. If, therefore, the house be "struck," it should follow that all danger would be obviated by the conducting influences thus in operation. Practically, the majority of our high erections of every kind are free every year from injury. We hope to make the reason of these apparent paradoxes evident in this article.

In experimenting with the most powerful friction electrical machine which has yet been constructed, it is found that in damp weather there is no difficulty in discharging a large Leyden battery completely. The same battery in dry weather could not be so completely discharged. In actual experiments the earth wires were connected with a 3-in. iron gas main, which, with the connected gas pipes, had a surface of several hundred square feet. But this arrangement of piping was also in direct connection with the street main in the largest thoroughfare in London. This fact of continued experience seems anomalous, but it has been easily extended in its application by other observers.

Armstrong, of Newcastle-on-Tyne, was the first to discover the production of electricity by steam, his first experiments having been carried on with a stationary boiler fixed in brickwork on an earth foundation. Subsequently it was discovered that a locomotive engine standing on the rails gave similar results. Now it is scarcely possible to find any circumstances in which ready conduction could have been more favorable. But still more recently the late Dr. D. Lardner endeavored to explain the cause of an explosion in a locomotive in the United States, while standing on a railway in an exposed condition. He conceived that the "electric fluid" suddenly decomposed the water and produced a mixture of hydrogen and oxygen which, coming in contact with the furnace fire, exploded. Of course the theory thus enunciated was simply ridiculous. But still this shows, with the cases we have already named, that some extremely anomalous circumstances exist which apparently contradict our received theories of electricity. From accounts we have seen, some singular phenomena in reference to lightning conductors have been observed in Italy. At the base of a conductor the earth was torn up and also scattered in all directions.

Now a careful consideration of the laws

of induction, conduction, resistance, etc., will lead to a satisfactory conclusion in respect to this occasional inefficiency of "lightning conductors," and also of the occurrence of fatal and destructive results either in the partial presence or entire absence of such so-called conductors. We have well-ascertained standards of the relative resistance of the conductors and insulators, and it becomes simply an application of known laws and facts to get rid of our difficulty. Nature helps us in the same direction.

The term "electric fluid" has lent much help to lead us into mistakes; but if we adopt it in their correction, we may find a solution of our difficulties. In a lightning conductor we have a metallic wand or rod by means of which rapid induction, and consequently conduction, takes place. The end of this rod is inserted in the earth, whose resistance is certainly not less than fifty million times more than that of the conducting rod. Consequently, when the charge arrives at the earth terminal of the rod, it receives a check. Let us fancy the case of a volume of water quietly passing through a 6 ft. main, at a pressure of, say, 100 lbs. per square inch. It passes off quietly. But supposing that suddenly a resistance of fifty million times its force be presented to it; the consequence would be fearfully destructive. Precisely the same result occurs where an inadequate pressure is made in the case of lightning conductors. The system of induction or conduction is interrupted, and the destruction of buildings is a natural consequence.

The question arises as to what remedy presents itself, and this is not difficult to answer. In nature we find that, despite the altitude of large trees, it is rarely that they are struck, provided that they are in a living condition. The reason of this is that every leaf and twig makes so many lines and points which favor the restoration of the electric equilibrium. It was stated at the Academy of Sciences, Paris, some years ago, that an ordinary haystack was a comparatively safe object in a thunderstorm. It is very rarely that they are injured. This remarkable fact is easily explained. If a piece of grass leaf be affixed to the nob of a Leyden jar it will be impossible to charge the latter. Arago, we believe, was the first to point this out. In nature, therefore, every leaf and twig is a pointed body, tending to combine, *gently*, the opposite electricities. But another provision exists in nature; the roots of all vegetable products, especially of large trees, extend in almost numberless ramifications in the ground. They thus have every chance of discharging electricity. Even in ordinary telegraphic practice a large earth plate is desirable. But the total tension of the most powerful voltaic batteries thus employed is infinitesimal when compared with the tension of the charge involved in producing a flash of lightning.

If we compare the above facts with those presented in the conditions of buildings in towns, we shall find that an entirely opposite state of things occurs. The top, roof, and exterior of our erections have all *rounded* surfaces, presenting no points of radiation such as those possessed by trees. The materials employed for building are all bad conductors, and when dry, as during hot weather, are really good insulators. The boiler seated in dry brickwork, already mentioned as having given to Armstrong the first hint as to making a hydro-electric machine, shows what an insulating effect dry brick possesses. The little metal work on the roof and in the water pipes also presents no "attractive" surfaces. Consequently, under such circumstances the restoration of the electric equilibrium is impossible, in many cases, without an explosion, which too frequently ends in loss of life and ignition of the house.

A great lesson, therefore, to be learned in erecting lightning conductors is to extend in all possible directions, their terminals beneath the ground. One of the best plans to effect this would be to connect at the bottom end of the conductor a large branch of wires bent outwards in all directions through *moist* earth. The importance of moisture cannot be overrated. This is instanced in telegraphic practice in Northern Russia. It is impossible to "get to earth" in rock that is hard, dry, and frozen. The lightning conductor may have been properly fixed, and of the best materials; but if, to use a popular phrase, it cannot "carry away the lightning," its use will be very limited so far as safety is concerned, and under certain exceptional occurrences it would be valueless, and fostering an idea of safety when there is really none.

The only proper material for a lightning conductor is copper, and in our opinion a flat band is much better than a cylindrical rod. The band is easily adapted to various ornamental and other projections of a build-

ing. Besides ramifying the bottom, it is also advisable that the top should be furnished with several points. Perhaps the following experiment will teach more than a long series of remarks on this subject. Two persons were placed in front of a hydro-electric machine of great power. It was carefully insulated, and the atmosphere was free from moisture. One of the persons was in a profuse state of prespiration, while the other was not so. The first presented a common nail to the machine while in action. The ordinary length of the spark was about 18 in., but it passed off harmlessly as a brush to the earth by the body without giving the slightest shock. The other person held in the hand a brass rod, ended by a small ball. On presenting this to the machine he was instantly thrown down, receiving a violent shock. This experiment has been repeated many times, always with the same results. It is highly instructive, and well deserves the study of all who have to do with the erection of lightning conductors.

A point of vital importance is almost constantly neglected in erecting a lightning conductor; it is that of connecting with it all the metallic exterior coverings, etc., of a building. In the ordinary factory chimney, of course, this precaution is generally unnecessary. But in the case of a church, this precaution is of the utmost importance. As a rule, the conductor is affixed to the steeple, carried to the earth, and there is an end of the matter. Iron roads are employed, and in the course of time, by oxidation and other causes, the rod breaks, and the value of the conductor is greatly lessened, if not destroyed. But on the roof are masses of metal, and between the stones clamps of iron. Now, for entire safety, every one of these should be put into metallic connection with the conductor. The reason of this is plain if the old idea of conductor be substituted by that of *induction*. Not only the conductor, but every metallic body is susceptible of induction, and isolated masses of metal may, therefore, become sources of danger. Consequent on this, instances have occurred in which injury to buildings has been caused, although they were supposed to be protected by a conductor. The following facts illustrate this. In experimenting with the hydro-electric machine just named, it was found that, although carefully insulated from a wooden floor on which it stood, shocks would be obtained whenever a person stood on any of the several iron rings which were let into the wood. The rings had no metallic connection with each other, nor with the machine. But by *induction* they became charged. So constant are these shocks that an experimenter who does not wear shoes protected by an insulating material, will be thrown to the ground and subjected to very severe shocks. Now precisely the same effect is produced in buildings in which metallic masses occur isolated from the conductor. An easy remedy presents itself; it is that of connecting all these masses by means of wires with the main conductor. The whole metallic portion of the building becomes one, and not only so, but every mass becomes an additional aid to the efficiency of the main conductor, and consequently the safety of the entire building is insured.

A similar precaution might be adopted in our houses at little expense, which at least would be of some value. Generally the chimney of the house is struck, possibly because the pot may be of metal. But there is another reason. The fine soot that lines the chimney is a conductor of electricity. Popularly (but not scientifically) the following results take place. The lightning gets to the iron stove, leaps across the room to any metallic or gilded article (such as a looking-glass), and for want of any other means of escape, in the absence say of gas fittings, it flies to the bell wires. These are frequently fused, not because they are too thin to carry the charge, but because they have no continuous conductor to the earth, their ends being always a bell hung high from the ground. No wonder then at last at the destructive effects of the lightning. A simple and efficacious means for protecting dwellings is to connect all the fireplaces, iron bedsteads, and bell wires by means of one wire to the iron rainwater pipe, polishing the surface of this at the junction, and contact being also insured by soldering. A house thus protected may be struck, but it would scarcely be possible that it should be seriously injured. Half a pound of No. 16 gauge copper wire, costing about one shilling, would thus protect each of the great majority of houses in an ordinary town, and induce an amount of confidence which would banish that sense of fear which many persons feel during thunderstorms.

We have witnessed some curious results in the case of accidents from lightning; some of these are at present inexplicable under our present limited knowledge of electricity. In cases of persons being struck, the coin or watch in the pockets has been partly fused, although of silver. A curious case came under our observation some year ago at Glasgow. Three persons had taken refuge under a tree; they were struck, although the tree was uninjured. The heels of all their boots, being heavily nailed, were torn off, but the persons sustained no serious injury. These, and many other facts we might adduce, show the necessity of connecting all metallic bodies with the main conductors to insure completely safety.

THE AQUEDUCTS OF ROME.

By J. B. PARKER.

From "Iron."

No city in the world was so well supplied with water as ancient Rome. The aqueducts traverse every part of it, and their remains are interesting, not only to the archæologist, but to the practical engineer, who would know how, in that hot and often dry country, such a boundless supply was maintained.

No less than nineteen aqueducts, or streams of water running through Rome, are enumerated in the "Regionary Catalogue" of the fourth century, but only nine are mentioned by Frontinas, who had charge of them in the first century, and who has left an admirable treatise on them. Some of the later aqueducts were merely branches from the main lines.

The principal aqueducts were brought from Sabiaco, 40 miles from Rome, and high in the hills. They were brought with great skill, and show very clever engineering. Where they were not tunnels they were large stone pipes; these stone pipes are each 6 ft. high and 2 ft. wide. They were not kept full of water, one-third of the upper part being left for air. They were brought by a very gentle descent to the city; the greater part of the way underground, but crossed the gorges on bridges sometimes 100 ft. high. The later aqueducts cross the Campagna for the last part of their route, at the height of 20 ft. or more above the ground, forming beautiful arcades. Of the latest and finest, there are still four or five miles of arcade remaining in Roma Vecchia. The greater part of this was destroyed in the sixteenth century to build a new aqueduct, which was constructed in the roughest manner from the old materials. The Aqua Alexandrina was choked up soon after it was built, in a singular manner, by stalactites; one of the springs used for it contained so much carbonate of line in solution, that it speedily filled up miles of the stone pipes.

The celebrated Aqua Marcia has recently been again brought into Rome. The company which has brought this excellent cool water into Rome consisted of English capitalists, aided by the late Mr. Shepherd. The engineers found it expedient to adopt the old plan of the time of the empire. For the first ten miles of its route the water is carried in stone pipes, and on arches where necessary, just as in the old manner. But, after descending the hill at Tivoli, it is carried in large iron pipes to avoid the detour the old aqueducts were compelled to take.

The Anio Novus is part of the river Anio itself. Great engineering works were made in the time of Claudius and Nero. A great wall, 12 ft. thick, being thrown across the river, forming a cascade. Beneath the surface, was the entrance to the aqueduct, so that, unless the pipe was full, no water flowed over the wall. This marvellous and successful piece of engineering continued in use for centuries. It was destroyed in the fourteenth century by an ignorant monk, who pierced the foundation to relieve a temporary flood.

The opinion commonly entertained that the ancient Romans were ignorant of the fact that water will always rise to its level in closed vessels is entirely a popular delusion. At every half mile of the aqueducts, on their course to Rome, each aqueduct forms an angle, to break the force of the water, and at that angle a great reservoir is made, with a filtering place at one end. This consists of four vaulted chambers, two above and two below. The water enters into the top of the first upper chamber, it then falls through a hole in the vault into

the first lower chamber, then passes through small holes in the intermediate wall into the second lower chamber, then rises through a hole in the vault into the second upper chamber, whence it follows its course at the same level as before. Each filtering bed is therefore built on the principle that water finds its own level. The large stone pipes were used because neither lead nor terra-cotta would withstand the force of the water. At the present time, the iron pipes of the new company burst so frequently that they fear having to relay the whole extent.

ON THE FIRE CLAY MANUFACTURE OF SCOTLAND.*

From "Proceedings of the Edinburgh and Leith Engineers Society."

The art of working in fire clay dates from a very early period, and is divided into numerous branches, one of which, namely, the production of good fire clay, I shall take up as the subject of this paper. Instead, then, of going back to the bricks of the most common description, as made in Egypt, or the more highly ornamental and artistic productions of Greece and Rome, the beautiful manufactures of chinaware in China or Japan, or the modern high class work in porcelain of Germany and France, the famous productions of Wedgewood and other great makers of pottery in England, with the elaborate and beautiful encaustic tiles and tesseræ of Milton, I shall, as already stated, confine myself specially to the manufactures from fire clay, as a branch of industry that has gradually and steadily risen to a position of great importance among the industries of this country. Pure fire clays consist of silica and alumina, and as such are perfectly infusible in the strongest heats to which they may be exposed in furnaces; but these are never in this pure combination. Various quantities of lime, magnesia, oxide of iron, etc., are usually in the compositions of these clays; and where these impurities exceed 5 per cent. they are positively injurious, for, acting as fluxes, they render the clay liable to fuse at an intense heat, which so far neutralizes the refractory qualities for which fire clays are so much valued in making fire brick gas retorts and similar articles which have to be exposed to very high temperatures.

Fire clays are found amongst the coal measures, and at the "outcrop" can be opened up into workable condition at comparatively little expense, by what is called, in mining phraseology, a "dook," or "igneoring eye," being driven into the seam itself, from which levels branch off each side, similar to those from the bottom of a vertical shaft. In either case the usual operations in mining must be carried out. There are two general systems of working out the clay, namely, by "longwall" and "stoop and room;" the former is only applied where seams not exceeding 3 ft. thick are found, and as the most of fire clays in Scotland vary from 5 ft. upwards, the latter system is more extensively adopted. It consists in driving passages in such a manner as to divide the clay into rectangular pillars or stoops, in this way as much being left on as what is taken out, the usual size of stoops being 20 to 25 ft. square, which supports the roof.

Fire clay presents the appearance of a species of rock, is very tenacious, and in loosening it in the mines a considerable quantity of blasting powder is used; it is taken in small "hutches" to the bottom of "dook," in pieces somewhat resembling rubble stones in size; these are drawn to the surface by means of an engine, and the clay deposited, which with a few days' exposure to the atmosphere becomes disintegrated, and in consequence is more easily ground. The first process in the manufacture of goods to which it is subjected is pulverizing in a dry state. This is effected by means of the "riddle mill," which consists of a circular iron pan, 7 ft. in diameter, driven by a vertical shaft through its centre; in this pan are two massive iron rollers, each weighing about three tons, fixed to a horizontal shaft working between slides at each extremity, the circular motion of the pan communicating the motion to the rollers. The fire clay is taken from the heap and thrown into this mill, scrapers being suspended from iron bars, and set at such an angle as to keep the rough clay continually before the rollers, these rising

* Abstract from "The Iron World and Manufacturer," of a paper read before the above Society by Mr. Wm. Wilson.

and falling according to the quantity put in, being guided in this by means of the slides already referred to. From the outer edge of the rollers to the inner rim of pan are perforated plates, through which the clay falls after being reduced to a comparatively fine powder, and these plates being movable, finer or coarser ones can be substituted when necessary. The sifted clay falls into a ring, and attached to bottom of pan is a blade or scraper, which removes this clay every revolution, and lodges it into a recess, from which it is taken by elevators to the pug mills and batching pans, to be brought up with water to the proper consistency for the production of the various articles to be manufactured either by hand or by machinery.

Pug mills are extensively used in most of common brick fields, but generally in fire clay works have in addition a circular iron pan fitted above, with rollers working in same; into this pan the clay is received from the elevators, and mixed with water in the first instance; the bottom of the pan is of very heavy plates perforated, on which the rollers revolve in the same way as the "riddle mill," and force the wet clay into the pug mill beneath. This pug mill is a very strong cylinder, cast perfectly true and erected on a massive stone foundation with iron basement, is fitted up vertically, and stands about 5 ft. high and 3 ft. diameter, widening at top in bell mouth style to the diameter of pan above. Inside is a vertical shaft passing through its centre, to which a number of knives are fitted set at angles, so that when it revolves the clay from the pan above is thoroughly tempered and gradually pressed to the bottom of cylinder, and forced out at the door on side, from whence it is conveyed to the makers. The batching pans are similar to those already described, with the exception of the bottoms being entirely close; these pans are used for producing finer qualities of clays, and rendering them more tenacious; they do not empty themselves as in the case of the others, so that a greater amount of hand labor is brought to bear on this portion of machinery.

Before adverting to the various processes of manufacture, I have to remark that these are carried on in stoves, flues being underneath the floors, about 20 in. deep and 14 in. broad, covered over with fire clay tiles, all these flues concentrating in one main leading direct to the chimney, regulated by dampers so arranged that the heat can be retained on any particular part of the stove, and carried right through as required. The heating of these floors is got by introducing the waste steam from the engine into the flues, by utilizing the heat from burning kilns in the same way, or by independent furnaces placed in the ends of the stove, and fired with dross, thus drying the material making, and allowing manufacturers to continue their operations to the full extent in all seasons. Bricks form one of the leading articles manufactured from clay, and have given rise to another very extensive branch of industry, namely, the production of brick making machinery, upon which no small amount of capital has been expended, and mechanical skill exercised to such an extent that numerous useful and ingenious inventions have resulted, considered of so much importance by their respective designers, that the majority are to be found on the patent lists. The cost of moulding the bricks, however, bears such a small proportion to the total cost, that machinery in this department can only be employed to advantage when large quantities are required within a very limited period, so that in point of economy the making of bricks by hand still maintains its position, and it is not to be supposed that the latter process is necessarily slow, as with the usual attendants a good brickmaker can produce 5,000 in ten hours, and there are instances where this has been exceeded. Brick moulds are made of wood and brass, and in many common brick fields iron moulds are used exclusively. The mould is simply a box without top or bottom, and made in the proportion of an inch and a quarter to the foot, larger than the brick required, which allows for shrinkage in the process of drying and burning; when made of wood it is shod all round the edges with iron, to prevent it wearing down by the working of the striker; it is also frequently lined with brass, but when the latter is used it is much better to have the mould complete in the metal, and these are very much adopted, in consequence of the very fine edge which they impart to the brick. In the making of fire bricks there are two processes, namely, dry stock and slop moulding, and each is accepted with equal favor, according to the accommodation or arrangement of the various works. There are more attendants at the former than the

latter method, in consequence of which the brickmaker can produce the greater quantity, but this is again contracted in the drying, as while the dry stock bricks are laid on the floor or edge those made by the slop system are laid on flat and dried, and ready to be removed much more quickly. For the making of bricks by the latter system the clay from the pug mill is deposited on one end of moulding table; fully as much as will form a brick being taken from this by the moulder, he dexterously gives it rude shape, and dashing into the mould, presses it down by hand, so that all the corners are filled up; he then removes the superfluous clay by means of a wooden striker, which is thrown into a water box before him each time after using. The brick being now moulded, a boy carries it away, mould and all, and empties it carefully on the floor on its flat, returns with empty mould, and dips it in water ready again for the moulder, who by this time has another brick in a second mould which is taken off by the boy in the same way, and this is continued till the day's work is completed. The only difference between this process and "dry stock" is that in the latter the moulder has a boy alongside of him, who in the first place forms a piece of clay approximate to the mould, which necessitates another boy on the opposite side for emptying it, and this is done on a thin board rather larger than the mould; the carrying off boy then covers the upper side with another similar board, and, gently laying it on its edge on the floor, slides the boards off, and returns with them to continue the operation. These bricks after remaining on the stove floors for twenty-four hours, are sufficiently dry to be removed to the kilns to be burned, about 25 per cent. of their weight as moulded having been evaporated; and I may state that any less water than this being thrown off would have the tendency of causing the bricks to crack and split when the extra heat of firing in close kilns was applied. Pressed bricks are prepared by taking the ordinary bricks when partially dry and putting them through a pressing machine, of which there are various constructions. A very simple and effective machine, and one very much in use, consists of a cast-iron mould the size of the brick, fitted into a very strong iron frame; this mould is let down the inside of framing by means of an eccentric, which allows the brick to be put in on a flat sole, level with the top of the same mould; a handle is attached to this eccentric, which on being drawn lifts the iron box or mould which encloses the brick; it is then compressed by the action of a very powerful lever wrought by hand, which is attached to the piston in connection with the sole plate on which the brick was at first placed; the pressure is thus communicated by this lever forcing up the sole plate, causing the brick to be fixed between it and a die suspended from the upper part of the machine by two strong bolts. This being accomplished, the lever and eccentric are allowed to take their original vertical position till the pressed brick is removed and replaced by another. In all machines for this purpose particular attention must be given to see that the mould is made of sufficient strength, that it shall in no way yield when the lever is applied, and that it and the piston fit each other exactly; when this is not the case a "feather" is formed round the edges of the bricks in consequence of the clay having egress when it is under pressure. Bricks pressed in this way are of denser texture, require more care and time in drying, but when properly prepared take on a beautiful finish, with very sharp arrises, and are much used for facing purposes in buildings. There are many varieties of bricks, but, the process of manufacture being similar to what I have sketched, it is unnecessary to enter into this, so that I shall now follow the dried bricks to the kiln. Kilns are of various constructions, and differ very considerably in their dimensions. A very old style of kiln is still in use, and produces very good material; it consists of a rectangular building, the side walls of which are about 12 ft. high, and from these is thrown a semicircular arch; the floor of this kiln is sunk 3 ft., and is divided into flues by dwarf walls being built, and the flues thus formed are arched over at the ends with the best fire bricks to form the firing ports; these flues extend the full breadth of the kiln, which averages 12 to 14 ft., and the dwarf walls are carried up level with the arch of firing ports, and to form the floor of the kiln are covered over with fire tiles, with spaces left alternately about 4 in. square, which allows the heat to spread amongst the raw material. On the top of the arch are several small chimneys, rising 2 ft. or so, communicating with the interior of the kiln, thus forming an outlet for any damp-

ness that may be expelled in the first stage of firing, and also creating a draught which is regulated by the firemen with small fire clay dampers. The walls are usually 18 in. thick, and in this form of kiln are supported by spandrels on each side, springing 8 ft. or so from the bottom of walls or firing ports. The coals are taken in here, and the whole being covered over, makes the position of the fireman, at this season especially, in comparison with other sorts of work, very desirable. Round kilns on this principle are also in use, but those in general favor in the majority of fire clay works are termed "Newcastle" kilns, and are found to be the most economical open kilns in use. Unlike the first mentioned, they are fired from one end in single, and from both ends in double kilns. They are usually fitted up in stacks of four or six together, all parallel to one another, each measuring about 16 ft. long, 12 ft. wide, and 10 ft. high. The entrance to these is from the end at which they are fired, and the door being built up with loose bricks after the kiln is filled, it is then used as a firing port; or the door may be in the opposite end, and simply built up with loose bricks and plastered over. In placing so many kilns together the one acts as a support to the other, so that only the outside walls on each side of the "stack" require buttresses which are of considerable weight, and in many cases built the full length of the kilns, so as to have the greater effect in counteracting the lifting caused by expansion when they are on full fire. In the back wall of each kiln are three ports or flues leading into one main flue outside, communicating with a very large chimney, which works the whole "stack," each kiln being regulated by dampers in connection with their respective flues, so that each or all can be in operation at the same time without the one in any way interfering with the other. In the double kilns on this principle the only difference in arrangement is that they have independent chimneys of smaller dimensions, with two to each kiln, placed respectively on the sides, each chimney being connected to the interior with two flues (one on each side), which work the whole.

In the setting of the kilns a great deal depends, and for this purpose very experienced workmen are required. There being no flue or riddle to the last description of kilns, the bottom is levelled over with fine loose sand, on which dried bricks are laid down on edge a little apart from each other; these are set two deep and form numerous narrow flues running into a cross flue at the back of the kiln, which communicates with the flue ports already noticed, so that these bricks, while forming the flues, are burned at the same time. Across them another brick is placed, and the setting continued till the kiln is filled, generally header and stretcher. At works where a miscellaneous trade is carried on a very great variety of articles are burned at the same time, but in all cases the floor is covered with bricks, as described; paving tiles, flue covers, copings, etc., all starting from the top of the third course of bricks, and arranged in such a manner as to give a proper draught, and allow the heat to be equally diffused through the kiln, thus contributing to a great extent to the economical application of fuel, which is a very important desideratum. On each side of the door, which I already remarked was formed into a firing port, is another firing port, into all of which the fire is introduced, and the loose bricks are plastered over with wet clay to prevent the ingress of cold air. For firing purposes, dross, chirls and chew coals are used, and it is immaterial which may be recommended, for the saving in the price of the former over the latter is lost by the extra quantity consumed and the extra time necessary to get up a proper heat. After a kiln has been lighted the firing must be brought on very gradually, to prevent the material from cracking or splitting, which occupies from 48 to 60 hours. The actual firing then begins, and takes as much more time, at a consumption of chew coals varying from 15 cwt. to 20 cwt. to the thousand bricks, and to other materials in proportion, a further shrinkage having taken place of about 10 per cent. The heat being all introduced from the front of the kiln, the materials immediately adjoining must of necessity be burned before those at the other end; but to prevent any overheating, port holes are opened to admit cold air in front, which not only neutralizes the effect of the heat at that particular part, but urges it backward, the firemen being guided by several small openings at the top of the arch, through which they can observe the progress of the firing from time to time, so that the contents of the kiln may be of uniform hardness when this operation is completed.

The cooling process then follows, which takes about three days. This must also be carried out very gradually, as a sudden ingress of cold air upon the material at this stage would have a similar effect to that of heat rushed suddenly upon the raw material. Attempts have been made to cool down kilns more speedily by introducing heated air with fanners, and gradually reducing the temperature; but this has not being found to be advantageous, greater attention having been giving to utilize the surplus heat, by introducing it into stoves for drying purposes, or by arranging the kilns so that it may be conveyed to another kiln in its first stage, and in both there has been a considerable amount of success. To the manufacture of the heavier materials in Scotland has been added within the last thirty years another branch of very great importance, namely the manufacture of glazed sewerage and water pipes. The improvements in the sanitary arrangements throughout the country, and the many water schemes which have been carried out of late and in progress, have tended very materially to the development of this branch of industry; the improvements in machinery, whereby these pipes can be manufactured at a considerable reduction from their original cost, their anti-corrosive properties, and complete freedom from the action of acids, render them (unless where very great pressure is required) preferable either to lead or iron. These pipes are made from 2 in. to 3 ft. diameter. One of the machines used in their production consists of a cylinder, with a vertical shaft through its centre fitted with knives, same as the pug mill, fixed on heavy logs, supported by massive iron columns, the bottom of which is generally about 4 ft. from the floor; it is perfectly open throughout, and about 4 ft. long; placed vertically across the top is fixed a strong cast-iron bracket in the form of an arch, so as to allow full clearance for supplying the machine with clay; this being the main bracket, a thrush bush is used, grooves being about 1 in. broad, corresponding to collars of same size in vertical shaft, which forms the main bearing; the shaft extends about 3 ft. higher, at which extremity it is supported by another bracket carried out from the wall, so that the whole working is effected with these two bushes. The cylinder has a large flange on bottom side about 2 in. broad, to which the "dies" are bolted; the "dods" in the centre of these "dies" being respectively the interior diameter of the pipe required, with the shrinkage added, while the space through which the clay is pressed gives the thickness; on each side of the machine is fixed an iron rod, and these rods act as guides for a carriage, on which a board is placed to receive the pipe; this carriage being suspended by chains attached over pulleys to heavy weights, is forced down these rods by the pipe, when being pressed out, and the required length being gained, the cutting apparatus, which is attached by a frame parallel to the bottom of die, is brought into operation, when a thin wire is drawn across. The board with this pipe is then carried away, the weights take up the carriage to its original position, and the same operations are continued. The pipes being thus got as plain cylinders, they are then threaded to form the spigot ends, and the other ends roughed to receive the faucets, which, during this operation, are being prepared by another set of hands from moulds of plaster of Paris. In making these, several moulds are required and two men; one forms the clay into a long roll and passes it to the moulder, who presses it firmly all round; a cutting gauge is then used to make it of the requisite thickness, and to give sufficient clearance for jointing; the threading gauge is then put on, which is made of wood with teeth shod with iron, corresponding to the number of threads required, and is firmly held against the inside of this mould after it is filled with clay, when the wheel on which it is placed is caused to revolve and the gauge removed with a gentle sweep by the hand when finished; the second man carries this away, and, laying it down, returns with another mould which he has emptied, and prepares a roll of clay, when by this time the moulder has a third mould filled, and so on. These, along with the plain cylinders, stand about twelve hours under a gentle heat, as for further operations a greater stiffness is required, in order that their form may be retained perfectly true. The next operation is the fixing of the faucets, and in the first place particular attention must be given to see that both are of uniform stiffness, as, if not, unequal shrinkage would take place, and the clay joining all round would have a tendency to crack. The roughest end of the pipe is now covered over with "slip" or soft clay

by a boy, the faucet which has also been roughed on the underside, is then put on level, and the workman with a board gives it a "tap," while a third works on the shoulder, which joins the two completely; the pipes then remain over another twelve hours, when they are sufficiently dry to be handled and wrought upon without in any way affecting their form; the superfluous clay at the joining inside of the pipe is then cut away with a knife by one of the men, while others follow with pieces of fine leather to smooth the whole surface, after which they are set aside another day to be thoroughly dried before being taken to the kilns to be burned. In this department it will be observed that division of labor is most extensively adopted, as, independent of the five hands attending the machine, other ten hands contribute each a part before a pipe can be said to be finished in the store. Spencer's patent is another machine of this class, the special object of which is to make the pipe with faucet attached. It consists of a plain open cylinder so that instead of the clay being taken down by knives, as in the one already described, it is forced down by a solid piston or plunger wrought by a steam cylinder fixed above; the "die" to form the pipe is attached to the bottom of lower cylinder, and underneath the "die" is fixed a mould to form the faucet; this mould being in two halves, opening and shutting by means of a hinge, and wrought by hand. The solid piston in connection with the steam cylinder rises as much above the lower cylinder as to allow the attendants to put in the clay, and this being done, the steam is put on to cause the solid piston to press out as much as will fill the mould, after which the steam is shut off and the mould opened by the attendant; the full stroke of the piston is then made and forces out the pipe to its proper length, which is then cut off and carried away. No doubt it looks a speedy process to have the pipe and faucet made all at once, but is not exactly found to be so in practice; in fact, most of the manufacturers in Scotland who have had these machines fitted up have dispensed with the faucet apparatus in connection, and made these in moulds by hand, while the machine only makes the plain cylinder; and considering that there is a stoppage every pipe to supply the clay, etc., everything considered, the former machine, with a continuous motion is generally preferred. The kilns in which this class of material is burned are chiefly on the Newcastle principle, both single and double, although a good many round kilns are still in use and work well. I accept the former, however, as the most economical, and the only difference from those already described is that these are generally larger, and have a "riddle" bottom—that is, the floor is formed of bricks 15 in. long, which cover flues 20 in. deep, these flues communicating with the main flue to chimney outside, as in the others. The bricks are made with a shoulder on each edge, extending about 2 in. at the ends lengthway of the brick, so that when two are laid together an opening of about three-quarters of an inch is formed from shoulder to shoulder, or 11 in. long, which is the breadth of the flue. This class of material having a less substance is more readily split; hence between it and the firing ports is built a wall about 6 ft. high, as a protection from the flames, and the heat, all going to the top in the first place, is drawn down by the arrangement of the flues in connection with the chimney. A very good size of kiln measures 24 ft. long by 13 ft. wide, from which take off the length about 6 ft. for firing ports and wall in front and there is left 18 ft. available to receive the goods, which are taken in by a door in the side or end. In filling these kilns small rolls or rings of clay are first laid on the floor, on which the first tier of pipes are set; a second tier is set above these, steadied by small pieces of clay put into faucets of the same, and the third tier is set into the second, this being carried on till the kiln is about two-thirds filled, after which only two tiers of pipes are set, so as to keep all safe from the sudden action of the flame. This space, however, is not altogether lost, as stable bricks and other material not so liable to be damaged generally occupy the front of these kilns; when filled the door is built up and plastered over as in others, and the fires being lighted, the process of slow firing and full firing is carried out, but the latter is brought up to a more intense heat for the purpose of glazing. This process consists of a quantity of the chloride of sodium, or common salt, being thrown into the fires at their greatest temperature, which is vaporized, and combining with the silicious particles of the clay, forms a uniform and durable vitreous coating, the flues in these kilns drawing he vapor down through

each pipe, so that the interior, as well as the exterior surface, is thoroughly glazed, and it is this which gives to bricks for paving stables, courts, footpaths, etc., curbs and gutters for streets, and similar articles, that degree of hardness and durability which, combined with their cleanliness and non-absorbent properties, recommend themselves as the most economical materials for the purposes for which they have been introduced, and now most extensively applied.

Terra-cotta is another branch of these manufacturers which, at the present day, is prosecuted with greater enterprise than hitherto; great authorities speak highly in its favor, even where stone is plentiful, but where there is a scarcity of the latter, buildings in terra-cotta are more frequently adopted, and it is not uncommon that decayed stones in ancient buildings are replaced by this imperishable material. To estimate the shrinkage which any design will undergo from being formed in a plastic state to its being turned out thoroughly burned, is one of the great difficulties attending this department, and when great exactness is required, burnt clay, after being reduced to a fine powder, is mixed in a certain proportion with the raw clay to diminish the shrinkage to the utmost. Many compositions are used in the production of it; for instance, in various parts of England the natural clays are mixed with varied proportions of kaolin or china clay, Cornish stone, ground flint, etc., to make up a durable substance, and this composition is held to produce very fine work.

A few years ago I executed several contracts in terra-cotta for the Science and Art Department, South Kensington, for the museum there, consisting of balustrading, friezes, cornices and other ornamental work, from the fire clay which I work at Lochhead, near Dunfermline, without mixture; and several English houses have also contributed some work from the same nature of clay. About that time a paper, bearing on the qualities of the various compositions from which terra-cotta is manufactured, was discussed by men of great experience in the architectural world, which resulted in the weight of argument being rather in favor of the clays from the coal measures. Terra-cottas are made in various colors, so that, when required for the replacing of decayed stones, the tints of the two may be exactly similar. The color is frequently merely washed on the surface, but in these cases the slightest chip or abrasion reveals a different shade, which is most objectionable, and it is, therefore, necessary that the color penetrate the whole substance. To effect this the coloring ingredient is added when the clay is in a dry state and properly mixed; it then goes through the batching pans, where water is applied to render it plastic, to be operated upon by the workmen. An endless variety of patterns are to be found in all departments of architecture, and the greater portion is wrought from plaster of Paris moulds by hand. The numerous designs in plain and ornamental chimney cans, so as to be in conformity with the style of the various buildings erected, form, themselves, a very extensive stock. Other architectural work, such as balustrading, columns, capitals, cornices, etc., and apart from the more useful productions, are the highly ornamental, such as fountains, vases, garden ornaments and decorations, all of which swell the list of manufactures from the fire clay, causing them to form a very important outlet for labor, in which no small proportion of skilled labor is required, commanding a rate of wages as high as two guineas a week. A class of work to which the highest skilled labor is applied is in the production of statuary, and, from the variety of processes through which it has to pass, it will be inferred that very great expense attends it. The first and most important part is to select an artist of undoubted skill, thoroughly acquainted with the plastic substance in which his design is to be cast, who completes the model; plaster of Paris is then made up to the consistency of cream, and poured uniformly over the whole surface to such a thickness as to give it a proper substance, and in this are placed small iron rods, which act as ties and give strength to the mould; the plaster of Paris now stands sufficiently long till it sets, and speedily attaining a firmness, it is inverted and the subject taken from it. The artist then examines the whole very carefully, touching up with a small tool any imperfection, after which it is put on the stove for a day or so to be properly hardened before the mould can be said to be completed. These moulds in various subjects are very intricate, and consist of numerous parts, all of which are fitted together in such a way that each of the

parts can be independently disunited. The clay for this department is specially prepared, and partakes to a great extent of the same process as in China ware in potteries. For this preparation a "ship plate" is used (which is simply a fire clay trough of considerable length), under which runs a flue, heated by means of a furnace at one end. The ground clay being soaked in water is put through a very fine lawn sieve into this "slip plate," and is heated by the furnace up to boiling temperature, and continued until as much water is evaporated as will render the clay of a consistency fit for use. It is then taken out and thoroughly beaten and kneaded by hand to drive out the air, and this being completed it is taken to the moulder. This very fine clay is now firmly pressed by hand into all parts of the mould, and these parts are all fixed together and properly jointed. To the clay has thus been imparted an exact outline of the design, which remains in the mould two days or so, until a degree of stiffness has been acquired, after which the various pieces of the mould are carefully removed. The superfluous clay at the joinings is now pared off with a knife, and the whole figure undergoes a process of very fine finishing, which is a special branch requiring very experienced and artistic workmen, and, in order to prevent sinking or twisting in those figures and designs that have the top part heavier than the lower, it is frequently necessary to provide supports at this stage of the manufacture. Statues, fountains and other similar productions on a large scale, where no duplicate is required after being modelled, are taken direct to the kiln and fired, retaining unimpaired the last touches of the artist.

The kilns in which the finer class of terra-cotta is burned are termed "muffled" kilns, from their being constructed with a casing (a brick thick), inside of which all the goods are placed, thus being thoroughly protected from the flame. A space about 4½ in. between this casing and the outside wall is where the fire operates, in the same way as an oven. The extra expense in heating up this description of kiln is very considerable, but there is not the risk of beautifully finished figures or designs turning out after being burned with scorched surfaces, as occasionally occurs in the open kilns; and while the casing only allows the heat to be brought up very gently, the highest degree of white heat necessary can be raised, so that there is not the slightest danger of any class of ornamental goods made from fire clay, when properly burned, giving way under exposure to the most severe weather.

Fire clay works in Scotland are carried on chiefly in the counties of Edinburgh, Fife, Clackmannan, Lanark, Renfrew and Ayr; and while the goods manufactured have a large and increasing home consumption, an extensive foreign connection is maintained.

THE HUMBER TUNNEL.

From "Engineering."

The bill for the tunnel under the Humber at Hull was lately rejected by the House of Lords after it had passed the House of Commons. The following description of the plans of the Engineer, Mr. Fowler, together with some of the objections raised against them while the project was discussed in the Parliamentary Committees, is given from the columns of "Engineering."

Hull—the third port in the kingdom, ranking after London and Liverpool alone—is placed in the anomalous position of having but one railway for its accommodation. This anomaly is doubtless due to its geographical position, separated as it is from the south by the broad and rapid stream of the Humber, the two miles width of which has hitherto proved an impassable barrier.

Mr. Fowler, however, was of opinion that in the present stage of engineering, such a barrier should no longer be deemed impassable, and he therefore matured an apparently bold, but in reality a cautious and tentative scheme for carrying the railway across the Humber by means of a tunnel laid by the pneumatic process in its sandy bed. The details of this scheme were fully elucidated in the evidence given by him before both Committees, and they are of the highest engineering interest; but we shall be unable, in the present instance, to do more than touch upon some of

the most salient points of the proposed pneumatic system of construction.

We may premise in the first place, what will be conceded by all, that if an ordinary rectangular pneumatic caisson, such as is used for bridge piers, be sunk to the requisite depth, it will be just as easy to build a short length of tunnel in the working air chamber at the base of the caisson as to fill in the said chamber with solid concrete—as would be done were it, as usual, made an integral portion of a bridge pier. It follows, as a corollary, that a number of isolated lengths of tunnels might, in this manner, be laid in the bed of a river, and that the only novelty involved would be as to the junction of these separate lengths.

It will at once be apparent that whilst in the case of the pier, a part, at least, of the caisson must be left in the ground, since the masonry is built upon it, in the case of the tunnel the caisson may be withdrawn, and the bed of the river may be restored to its original level.

The appliances pertaining to ordinary caisson work consist of pontoons for carrying the machinery and materials, with the requisite moorings for securing them in position, of the caisson itself with its working air chamber and shafts, of guide piles for regulating the sinking of the caisson, in connection with tackle for preventing the too rapid descent of the caisson before it has sufficient hold in the ground, and of weights to force it down if the ground has, on the other hand, too much hold on the caisson.

Now, in Mr. Fowler's design, the whole of these appliances are contained in one simple and efficient apparatus, which he terms the "working vessel." Three of these vessels, each equal to the construction of a length of 160 ft. of tunnel at an operation, were proposed to be employed by Mr. Fowler, and the following description of one will apply to all:

A rectangular pontoon 160 ft. long by 42 ft. wide, and 12 ft. depth, with a working air chamber or diving bell of similar dimensions attached to its bottom, and a deck for machinery carried upon columns at a sufficient height above the top of the pontoon to be clear of the water at all times, constitute the chief portion of the apparatus. The requisite air and water shafts, supply pipes, and other means of communication between the air chamber and the said deck, were also provided, and a number of screw piles and heavy mooring chains were ranged along each side of the pontoon, and worked by suitable steam-driven apparatus placed on the machinery deck. In addition to the working vessels, a few air-tight ballast barges were provided to perform a double function, which will be hereafter referred to, and it may be here noted that the pontoon itself was weighted with 1,200 tons of slag ballast.

The mode of constructing a length of tunnel by Mr. Fowler's process would be as follows:

The position of the first length of tunnel being determined, and a number of screw moorings with buoyed chains being fixed at the requisite points, the pontoon, with its self-contained appliances, would be conducted by steam-tugs, at slack water of flood tide, to its position between the buoys, and the mooring chains previously referred to as being attached to the pontoon, and worked by machinery on its upper deck, would then be secured to the buoys, when the pontoon would be hauled into a sufficiently exact position. The next step would be either to allow the working vessel to ground with the falling tide, or should the bed of the river not be suitable for such a process, to run down the screw piles whilst the pontoon was still floating, so that at low water the working vessel would be supported partly by its lower edge (which would to some extent have cut into the bed of the river), and partly by the screw piles. When fairly entered in the sand, the ballast barges previously referred to would be floated over, and sunk upon the top of the pontoon, the water would next be expelled from the working chamber by pumping in air, and men would then enter the chamber and get out the excavation by means of sand pumps and other well-known and economical expedients. When the excavation had reached a depth of 24 ft., the top of the pontoon would be level with the bed of the river, and as the sinking progressed the ballast barges would bury themselves in the sand, and so perform their second function, of keeping the sand from flowing over the top of the pontoon, and so impeding its subsequent raising.

The working vessel being thus sunk to a depth a trifle below that of the invert of the proposed tunnel, bricklayers would replace the excavators, and the lower half of a couple of single-line railway tunnels would be built by them in the air chamber.

At each end of the tunnel head walls would be built, with a view to exclude the sand, but not the water. The inner half thickness of these walls would be of brickwork, and the outer half of weak mortar, the utility of which will be apparent hereafter.

This work having progressed so far, it would become necessary to raise the working vessel to admit of the upper half of the tunnel being completed. To do this it would be first necessary to lighten the apparatus, and this introduces us to one of the most elegant features of Mr. Fowler's design, and the one which was persistently misunderstood by the opposing engineers throughout the entire case, to their own complete discomfiture in cross-examination. In Mr. Fowler's design complete control over the raising and lowering of the caisson is obtained by the simple manipulation of a couple of valves—an air valve and a water valve; and all irregularity of ascent or descent is checked by the screw piles attached to the sides of the vessel. As previously explained, both the working vessel and the barges are self-floated into position, and since they are heavily ballasted it is obvious that the admission of a few hundred tons of water would suffice to sink them; the admission of a further quantity would enable them to resist the upward pressure of air in the working chamber; whilst the admission of a still further quantity would supply the necessary additional downward pressure to overcome the friction of the sand against the sides of the caisson, which downward pressure, it is obvious, might be considerably increased at any time by inducing a slight temporary reduction in the pressure of air in the working chamber.

In the same manner the converse operation of raising the caisson would be effected by converse processes. Thus by expelling a certain quantity of water from the chambers of the pontoon and barges by the admission of air, the downward pressure arising from the weight of the apparatus would be neutralized, and by expelling a further quantity a buoyancy would be imparted to the apparatus, sufficient to cause it to overcome friction, and tear itself out of the sand if unchecked by the screw piles. This limit would not be approached too closely in practice, since screw-jacks were proposed to be used by Mr. Fowler as auxiliaries in the raising of the caisson.

Reverting, now, to the description of the construction of the first length of tunnel, the step subsequent to those already described will be to raise the caisson by the admission of air to the chambers in the pontoon and barges, and, by screw-jacks, to a sufficient height to admit of the upper half of the tunnel being built. As the raising progressed, puddle would be filled in at the sides of the tunnel, in the space previously occupied by the stiffeners and gussets of the air-chamber sides, and when the necessary height had been attained, puddle would be filled in over the top of the tunnel also. Dependence is not placed by Mr. Fowler upon the puddle solely to exclude the water, but, as the brickwork progressed, it would be paid over with a specially prepared elastic asphaltic mastic which would be perfectly impervious to water.

The first length of tunnel being thus completed, the ballast barges would be first floated off, and then the pontoon itself would be similarly floated, and moored in a new position. Assuming the adjoining length of tunnel is next to be undertaken, the working vessel would be moored as near as possible to the completed length, say, within 1 ft. of its end. Sinking would then be effected as before, and it will be obvious that in its descent the cutting edge of the caisson would shear through the weak mortar, which, as already explained, was placed at each end of the first length of tunnel. The 1 ft. space between that tunnel and the caisson would consequently be filled by an artificial film of self-sustaining mortar, instead of running sand, which would otherwise have been the case. When the lower half of the tunnel was complete the caisson would be gradually raised in successive steps, and during such raising the junction of the two lengths of tunnel would be effected as follows: The caisson being lifted, say, 9 in., the men would remove a portion of the weak mortar lying outside the edge of the caisson, and would so prepare a bed for the brickwork necessary to join up the two lengths, which bed would be kept clear of the sand, which would otherwise have flowed in, by the portion of the weak mortar film which would still remain. The bricklayers would then join up the two lengths by passing their hands under the edge of the caisson and bonding the bricks into the toothings of the old tunnel in the usual way. The

inconvenience, if not impracticability, of making the junction in this way was much dwelt upon when the Bill was before the House of Commons; so Mr. Fowler himself, as well as a practical contractor for him, determined to test the validity of the objection by the actual construction of a joint under analogous conditions. No difficulty at all was experienced in executing the work, and its soundness was well attested by the specimens produced in the House of Lords Committee Room. To still further silence objections, Mr. Fowler pointed out that the joint, if weak, could be readily reinforced by iron tubing, so that absolute immunity from leaking was cheaply attainable.

Such is a brief sketch of the scheme which was fully elaborated in all its interesting details for many days before Committees of both Houses of Parliament. We have not space to do more than refer to a few of the more extraordinary, and, we trust, unprecedented, objections urged against it by its detractors.

In the first place it was suggested that the caisson would tear up its moorings, as the current was great. It is said that a premise may be found wide enough to hold any conclusion, but as Mr. Fowler did not specify any particular number of screw moorings, but simply premised that he should employ as many as were necessary, the above diction does not apply in the present case.

In the second place it was maintained that the caisson could not be sunk, as the downward pressure was insufficient to overcome friction. Attention was called to the fact that Mr. Fowler proposed at intervals to effect a slight temporary reduction in the pressure of air in the working chamber, but it was answered that to obtain the required downward pressure it would be necessary to reduce the pressure to that of the atmosphere, and this conclusion would have been quite correct if, as was assumed, the pressure of air in a diving bell is dependent upon the height of the bell and not upon its depth below the surface of the water! Witness was very strong upon this point, so his evidence appears upon the notes unshaken.

But even if the unfortunate caisson could have been got down, it could not have been raised (so it was affirmed), for there were several thousands of tons of dead weight to be lifted by extraneous means, independently of the power required to overcome friction. It was suggested in cross examination that the opponents were tugging away at some thousands of tons of water which they had let into the pontoon and ballast barges, and which Mr. Fowler of course had stated would be removed before lifting was attempted. One witness actually stated at first that this would make no difference; but, thanks to the persistency of counsel, he was finally compelled to recant his scientific heresy.

But, according to the opposing engineers, not only would the caisson neither sink nor rise, but it would not even swim to its position without being in imminent danger of upsetting. One witness volunteered the statement, that if the centre of gravity were raised 3 ft., it would occur above the centre of buoyancy, and the rectangular pontoon "would turn over as a matter of course!" This witness had made the slight mistake of confounding the centre of buoyancy with the metacentre—that was all.

It is unnecessary to multiply instances of similar fallacies advanced to prove Mr. Fowler's scheme to be impracticable. It would appear almost incredible to us were not the printed evidence lying before us, that two past presidents and a vice-president of the Institution of Civil Engineers would venture to impugn the careful calculations of four members of equal rank in the same Institution, with so little previous preparation as the blunders perpetrated would evidence. We are aware that great engineers seldom devote much time to detailed calculations, but in the present case the fallacy of their conclusions was self-evident. Thus, in raising the caisson it should have been obvious that no dead weight would have to be dealt with by extraneous means; for as both pontoon and barges had been floated into position, so would they float again, and there would be the surplus flotative power of the free-boards of both, coupled with the buoyancy of the working chamber, available to overcome friction.

The statement that the pontoon would tumble over if the centre of gravity were ever so little above the centre of buoyancy, is even still more self-evidently monstrous. What would happen if a plank were cast into the water? The centre of gravity would be above the centre of buoyancy, and the plank, according to the theory advanced, would at once turn over. But even then it would be as badly off as be-

fore, and thus there would be no alternative for the unfortunate plank but to continue rolling and rolling, like the stone of Sisyphus, until relieved by the superior powers from its wearisome round.

Evidence such as this involves practical, though of course not wilful injustice. The confident statements of deservedly eminent engineers have justly great weight with the members of Parliamentary Committees, and the impression of these statements is not always effaced by a subsequent technical digest of the witness in cross-examination. It is for this reason much to be regretted that the eminent engineers who appeared against Mr. Fowler and his equally eminent coadjutors, should have been at so little pains to appreciate the details of his scheme. It would have been still more a matter for regret if the evidence of the former engineers had not been so completely demolished as it was by the singularly able cross-examination of the leading counsel of the promoters of this Bill.

ON FLOUR MILL EXPLOSIONS.

By STEVENSON MACADAM, F. R. S. E.

From "Iron."

Twelve months ago a violent, disastrous, and lamentable fire explosion occurred in a flour mill in Glasgow. A large building of five floors, besides a sunk story and attics, had its gable walls blown out, and was fired from top to bottom.

The operations which were being carried on were of the most peaceful description, and were simply the cleansing and grinding of grain, and dressing of the flour. All the processes were proceeding in the most regular and harmonious manner, and yet within a few seconds, two explosions took place; the mill was in ruins, the *débris* was simultaneously fired, the site of the mill was a roaring furnace, and out of twenty-seven work-people engaged in the mill, fourteen were instantly killed, one was mortally wounded, eleven were more or less severely burned, and only one, who was on an outer gangway, escaped unhurt.

The occurrence was so unusual, and at first sight apparently so unexplainable, that it called for a searching inquiry, in the prosecution of which Professor Macquorn Rankine and I were requested to take an active part. The results of the investigation proved two points.

First, that there was nothing unusual being carried on in the special mill referred to, which would render the operations more likely to lead to an explosion than in other mills elsewhere.

Second, that fire explosions of an exactly similar nature, though differing in degree, had taken place in other mills in this country, and on the Continent, though the public, and even scientific men, were unaware of such.

These facts enable me to take the particular case into the general question, and to discuss the subject simply in the light of an important public matter affecting one of the most necessary branches of technical science. The discussion of the subject will appear all the more necessary when I mention that, under the present arrangements of flour mills, there is nothing to hinder another disastrous catastrophe happening any day, and I feel it is a duty incumbent on me to afford every possible explanation of the manner in which such fire explosions have occurred and may still occur.

The nature of the operations carried on in flour mills may be condensed under three divisions.

1. The cleansing of the grain.
2. The grinding of the grain.
3. The sifting or dressing of the grain flour.

In small mills these operations go on day by day, with a minimum amount of risk, so far as fire and explosion are concerned. One or more pairs of stones, enclosed in a wooden frame work, reduce the grain to powder, and the mixed flour and bran are conveyed by a spout to a bin, from which it is afterwards taken to the dressing machines. Some of the finer particles escape into the atmosphere of the mill during the grinding and dressing processes, but the proportion is comparatively small, and, as a rule, is not sufficient in quantity to lead to a fire explosion. At the worst the fire explosion will be limited to the pair of stones which may strike fire, and possibly to the meal-spout attached thereto; or it may be localized in a dressing machine when a

light has been incautiously brought near the apparatus when in full work.

In a large mill, on the other hand, the danger of fire and fire explosions is much increased, for ten, twenty, or thirty pairs of stones may be at work at one time, and each of these pairs of stones may have a box-pipe, roan, or conduit attached, which leads to an exhaust-fan, and the latter, when in operation, sucks or draws all the the finer and lighter flour-dust up into a receptacle called an exhaust-box.

The practical results of this exhaust arrangement are, that the mill itself is kept more free from flour-dust floating in the air, and thus the men can work in a purer atmosphere, and that it accumulates all the fine and almost impalpable dust in the exhaust-box. Generally, the exhaust-box is connected with a second dust receptacle, called a "stive-room," where the fine flour-dust, which has not been deposited in the exhaust-box, is received. Occasionally the exhaust is assisted in carrying away the fine dust by a blast, or system of air blowers.

Now the tendency of the exhaust system is to centralize and accumulate in the exhaust-box and its connecting stive-room all the fine impalpable flour-dust which does not readily fall by its own weight through the meal spouts leading from the grinding stones, and, consequently, to store up, for the time being, those portions of the flour which can be most readily suspended through the air, and form a dusty atmosphere.

Simultaneously with the exhaust, there have been introduced improved cleansing machines, including decorticators and smutters, for the prior treatment of the grain, and improved sifting or dressing machines, for the more thorough separation of the different sorts of flour. All these improvements in milling have been carried out with the very praiseworthy purpose of perfecting the process, and of obtaining better and purer flour; but I am sory to say, they have at the same time brought about a condition of things in our large flour-mills which may at any time lead to fire explosion, as, in fact, has already taken place in several mills.

The chemistry of the grain and flour may assist us in arriving at an understanding regarding these fire explosions. The chemical components are principally starch and gluten, with small proportions of gum, sugar, oil, woody fibre, and ash. The starch and woody fibre are composed of carbon, hydrogen, and oxygen ($C_6H_{10}O_5$); so are also the gum, sugar, and oil; and the gluten contains these elements accompanied by nitrogen, sulphur, and phosphorus. All these proximate constituents are combustible when burned in the ordinary way, and are consumed with greater rapidity when diffused as a cloud through the air.

When the flour is showered from a sieve placed some distance above a gas flame, rapid combustion takes place, indeed the flour burns with explosive rapidity, and the flame licks up the flour-shower somewhat in the same way that it flashes through a mixture of gas and air, or that it travels along a train of gunpowder. Similarly, the flour blown into a cloud by a pair of bellows at once takes fire, and burns with a sudden and vivid flash. The smut taken from the grain during cleansing, and the sharps separated from the flour, burn with equal readiness.

Probably the best way of showing the explosive combustibility of flour particles, is to place some flour in a box lying inverted on its lid, introduce a light, and blow the flour into a cloud by bellows, when instantly the box is lifted from its lid and much flame rushes out. The fine division of the flour has necessarily much to do with the rapid combustion; and, indeed, coarse gunpowder can be passed through a flame without burning, while iron filings cannot fall through the same flame without being set fire to.

When bruised, the flour resolves itself into gases. The carbon, by uniting with the oxygen of the air, becomes carbonic oxide (CO) or carbonic acid (CO_2), and the hydrogen and oxygen become water vapor, or steam (H_2O). The volume of these gases is much increased by their high temperatures at the moment of combustion.

The conditions required to bring about a fire explosion are somewhat similar to those which cause a gas explosion. Coal-gas is combustible and not explosive, when unmixed with air, and it only becomes explosive when it is mixed with sufficient air to burn it. This proportion is obtained in the most powerful degree when one volume of gas is mingled with ten parts of air. A lesser or larger proportion of air lessens the power of the explosion by causing the gas to burn less quickly, and consequently with

less explosive force, and thus tending more to ordinary combustion.

The flour agrees with the coal-gas in being simply combustible when unmixed with air, and equally agrees with coal-gas in being explosive when mingled with air in the proper quantities. The fine and impalpable flour-dust must be diffused through the air in definite proportions in order to constitute an explosive mixture; and too little or too much of either of the components (flour and air) must lead to a lessening of the explosive force, and to a more gradual combustion of the flour-dust when such a mixture is brought in contact with a flame, or spark at a white heat.

In order to bring about the explosion, it is necessary also that the flour-air mixture be confined within a given space; hence, if the flour be incased in a box with the lid fastened down, and the bellows be brought into play to produce a cloud while a light is introduced, the box will be forced open with a loud explosive noise, and the side be split up, while weights placed in the box are thrown off.

In fact, an explosion is brought about which resembles in its effects that of gunpowder, gun-cotton, or coal-gas and air. All of them burn comparatively quietly when fired in open vessels; it is only when enclosed, and resistance is offered, that the noise and other effects of a true explosion are observed. No doubt gunpowder and gun-cotton differ materially from the other explosive agents, as both the gun-cotton and gunpowder contain within themselves all the oxygen or air required to burn them, and thus do not need the admixture of air so essential to the explosion of coal-gas and flour.

The order of explosions in flour-mills may now be referred to. The more common way of the production of the spark or flame which fires the flour-air explosive mixture is the feed going off the stones during work, when the stones set down on each other, and as they are of a flinty and hard silicious rock, and are revolving at from 100 to 160 revolutions in the minute, they quickly strike fire and become very hot.

The feed may go off for want of grain in the hopper, or from some obstruction in the feed pipe. A spider's web actually stopped the feed in one case, and led to a violent explosion in a mill, a detached stive-room luckily suffering most. Even when the feed is kept on, a nail finding its way into the hopper and down between the stones instantly strikes fire, and the minute particles of molten conbustible iron inflame the flour-air mixture, and cause an explosion. This actually happened in a Scotch flour-mill.

Probably the greatest danger is when the feed is suspended for a short time. The stones settle down and strike fire, and then the feed comes on again, in which case much inflammable flour-dust will be instantly produced and fired, and the exhaust will suck in the flame through the roans or conduits leading into the exhaust-fan and exhaust-box.

In several flour-mill fire explosions, the crackling noise of a running fire has been distinctly heard traversing the "roans," or conduits leading from the stones to the exhaust-fans. In some cases the explosion goes no farther, and may simply blow open the fan-box cover, as in one case in Scotland. If the flame passes the fan, however, it gets into the exhaust-box, and everything depends upon the momentary condition of the exhaust-box at the time, whether the explosion ends there, or the mill itself is blown up and fired. If the dusty atmosphere be at a minimum, the explosion will be comparatively feeble, and will probably end in the blowing out the side of the box, destroying some of the windows of the mill, scorching a man or two, and loosening some timbers and slates, besides charring all woodwork within reach of the flame.

But, if the mill is in full working order, and much dust is being carried into the exhaust-box, causing the flour-air mixture to be abundant, then the explosion will be violent, the sides of the box will go, and the fine impalpable flour dust lying on the floor and shelves will be blown into the atmosphere of the mill, when a second explosion will occur, and the mill itself must go—not only on one floor, but the explosion of the exhaust-box will cause a disarrangement of all the air-courses, and the mill being in communication on all floors by means of elevators, hatchways, and other passages, and the cleansing and sifting processes proceeding at other parts, there must be a simultaneous production and firing of more or less flour-air mixture in all the floors, and consequent explosion. A period of darkness, caused by the flour-dust being diffused through the atmosphere of

the mill, has been distinctly observed before the main firing of the mill.

The connection of the exhaust-box and the stive-room has much to do with the direction which the explosion takes. Thus, if the mode of communication be by a wooden roan of small size—say a foot in diameter, as in many mills—the force of the explosion in the exhaust-box cannot spread itself in the direction of the stive-room, and must burst the sides of the exhaust-box, and force the explosive flour-dust mixture into the mill itself. But if the communication is capacious enough, say 3 or 4 ft. square, then the explosion in the exhaust-box will find vent into the stive-room, and the latter, instead of the mill, will suffer.

In the case of one mill, where the latter conditions were carried out, the walls of the stive-room were blown out and the building wrecked, while the mill itself escaped with some charring of the wood. The stive-room in this instance was outside the mill, but the safety derived from the comparative free communication between the exhaust-box and the stive-room, would have been entirely negatived if the stive-room had been simply on another floor of the mill.

The chemical and physical results of the fire explosion may now be considered. An ordinary size of exhaust-box is 18 ft. long, 9 ft. high, and 7 ft. wide. The capacity of this box will therefore be 1,134 cubic ft., of which fully a fifth will consist of oxygen. The quantity of coal-gas required to mix with this amount of air, so as to form the most powerful explosive compound, is about 113 cubic ft., or, taking the density of the gas at 500 (air=1,000), less than $4\frac{1}{4}$ lbs. of coal-gas. It is well known how disastrous such an explosion would be in its consequences, and yet only $4\frac{1}{4}$ lbs. of coal-gas would take part in it. With flour-dust, however, diffused through the air, instead of coal-gas, the proportion of oxygen contained in the box (about $17\frac{1}{2}$ lbs.) would instantly burn 28 lbs. of the flour-dust into carbonic oxide and water-vapor or steam, being fully six times the proportion of the coal-gas which could be consumed with the same amount of oxygen.

The sudden combustion of the flour-air mixture at a white heat necessarily produces great increase in the bulk or volume of the gas, and when the whole conditions required theoretically for the production of the most powerful explosion possible are practically realized in a mill, the increase of pressure is equal to eight atmospheres, and quite sufficient to cause the total destruction of any ordinary building.

The precautions to be taken in the future for the avoidance of flour-mill fire explosions must necessarily lead to the removal of exhaust-boxes, stive-rooms, smut-rooms, and other receptacles of flour-dust, to the outside of the mill, and it will be better if they can be placed at a side of the mill where there are no windows. There should be no direct communication between the mill and these places, except by the comparatively small spout or roan conveying the dust from the cleansing, grinding, and sifting processes; and it will be better if the roans be provided with sliding or hinged valves, which would close at once if an explosion occurred in any of the dust receptacles leading to a back draught.

The great sources of danger are undoubtedly the exhaust-boxes and stive-rooms, and these should be constructed either entirely of boarding, so that the explosion might readily find vent by bursting open the planks, or, if built of brick or stone, the frame work of the windows or other compartments should be loosely set in the building, so that they might readily give way when an explosion occurred. In Scotland there are mills more dangerous in their construction than those in which accidents have happened; in one mill in particular which I might name, the exhaust-box is on one floor of the stive-room on the floor above, both forming part of the respective floors of the mill, and only separated from other parts of the mill by a wooden partition. If the necessary train of combustible and explosive dust leading from the stories through the exhaust-roans and fan, exhaust-box and stive-room, be complete through the full working of the mill, and a pair of stones strike fire from any cause, the mill I refer to can hardly be expected to escape a more or less disastrous explosion.

Not only should the exhaust-box and stive-room be outside the mill, but the danger will be lessened if the exhaust-fan be also placed outside. It can readily be put into the entrance of the exhaust-box, or in a corner thereof. Should an explosion then occur through the stones striking fire, it will be limited to the exhaust-roans, so far as the mill itself is concerned, and the fan will tend to suck the flame out of the mill. No one should enter the exhaust-

box or stive-room during the working of the mill, and the cleansing out of these places should be carried on when the stones are not grinding.

No naked flame or light should be taken into any of the dust places, and all gas jets and lamps should be protected with glass and wire-gauze coverings. Naked flames often lead to minor explosions in flour mills, such as the firing of the dusty atmosphere in the dressing machines, and in some cases in the mixing rooms, where the different sorts of flour are ultimately incorporated together.

I trust that this paper will awaken the proprietors of all flour mills to a sense of the necessity of adopting all precautions and measures to arrest flour-mill fire explosions for the future. The plea of ignorance of the explosive nature of the flour-air mixture cannot now be pleaded.

I do not blame mill-owners, however, for their want of knowledge in the matter of the powerful destructive force capable of being excited by a flour-mill fire explosion, for even science had not uttered a warning cry; and I know that the ablest scientific mill-engineer in the country, when asked for his experience and opinion in regard to such explosions, at once replied that he never knew of a mill being blown up by a mixture of flour and air, and that he did not consider it likely or probable that such could be the cause.

Even the chemist to the War Department was impressed with the novelty of a mill being blown up and fired by flour-dust diffused through the atmospheres of the different floors, and wrote to me for the fullest particulars. And, to be candid, when I entered upon the inquiry I scarcely entertained the idea that a flour-mill could contain such elements of destruction within its ordinary operations; and it was only after organizing and carrying out many experiments, and fully considering the whole subject, that I was forced to the conclusion, which theory as well as experiment can now substantiate, that the ordinary arrangement of a modern flour-mill renders it liable, any day, to explosions of, it may be, a very serious character.

THE INTERNATIONAL PATENT CONGRESS.

From "Engineering"

The first International Congress, convened with the object to discuss the question of patent right and to lay down—on the basis of the experience of various countries, and the materials collected—fundamental principles for an international reform of patent legislation, has finished its labors. After five days of assiduous deliberations, which were at times rather animated, its business has been brought to a close, for the present. If there was any incredulity evinced at the commencement, notwithstanding the importance of the subject, as to the probable success of the meetings of the Congress—and it must be admitted there was great doubt expressed in this respect, and in the utility of the Congress in general—it was dispelled by the proceedings, which have taken a course so satisfactory and successful as to surpass the sanguine expectations of the most strenuous advocates of patent right, and the assimilation of the legislation of the different civilized States of the world in this respect.

On Monday, the 4th inst., the Congress met for the first time in the Grand Hall of the Jury Pavilion in the Exhibition grounds. There was a large number of members present—men of science and practical ability, engineers, political economists, members of the legal profession, representatives of the higher branches of industry, inventors and manufacturers—all men of high standing and reputation in their respective spheres of life, from various countries, the learned element of Germany predominating. There was but a small number of Englishmen present, but the Americans from the United States mustered very strong. In fact, the latter as a body, and some of their leading men, such as Professor Blake, Mr. Hamilton Hill, and others, have taken throughout a very lively interest and most active part in the matter, as well in its preliminary stages as at the public meetings. As already mentioned in our previous report on this Congress, a preparatory committee had been appointed in accordance with the general programme, whose duty it was to prepare the materials to be laid before the Congress, to elaborate

the matters of inquiry, and in general to prepare all the preliminary matters for the opening of the Congress. This preparatory committee was composed of gentlemen from all parts of Germany, Austria, England, and the United States of America. No Frenchmen, no Italians, no gentlemen, in short, of other nationalities, have taken part in the Congress. The foreign Governments were represented—not officially—by delegates to report the proceedings to their respective Governments; they were Mr. J. M. Thacher, Assistant Commissioner of Patents, of the United States of America; Mr. Thomas Webster, Q. C., of London, for England; Professor Klostermann, of Bonn, for Germany; Professor Baumbauer for Holland; Mr. Adolfott for Switzerland; Commentatore Codazza for Italy; and Mr. Fraenckel, Railway Director of Stockholm, for Sweden.

His Excellency Baron von Schwarz-Senborn, as Director-General of the Vienna Exhibition, opened the Congress with an address of welcome, delivered in both the German and English languages, expressing his conviction that scarcely any other of the different Congresses to be held in connection with the Vienna Exhibition will be of such an importance and international interest as this Patent Congress, which was the first of its kind. The apprehension that the accumulation of new inventions in the Exhibition would act detrimentally upon them by their exposition and publication, had greatly limited the number of objects of that kind, which would otherwise have been sent to the Exhibition. But by the law of November 28, 1872, a protection had been granted for all exhibited new inventions and patents, which, if applied for, would even be extended for a longer time, which would secure exhibitors against piracy of their inventions. The President of the Imperial Commission, Archduke Rainer, highly approved of the meeting of the Congress, and would follow its deliberations with the greatest interest, and the Minister of Commerce, Dr. Banhans, had desired him to submit to him a full report of its proceedings.

This formality over, the Congress proceeded to the appointment of its officers, and elected by acclamation, on the proposition of the preparatory committee, His Excellency Baron von Schwarz-Senborn, honorary president; Mr. William Siemens, C. E., London, acting president; Mr. Thomas Webster, Q.C., London, Government councillor; Dr. Franz Neumann, of Vienna, Dr. Werner Siemens, of Berlin, Dr. Engen Langen, of Cologne, President of the Society of German Engineers, and Mr. Hamilton Hill, of Boston, United States, vice-presidents, to which number was added, on the proposition of Baron Schwarz, Aulic councillor, Chevalier von Engerth, of Vienna, and the chief of the Patent Office in Vienna, Dr. von Rosas, Dr. Ratkowsky, Vienna, Professor Dr. W. F. Esner, Vienna, Dr. Rosenthal, Cologne, Mr. Carl Pieper, C.E., Dresden, and Professor Blake, New York, and Mr. Kaupe, of St. Petersburg, secretaries.

The meeting having adopted the order of proceedings, and the rules to be observed during the debates, the Congress entered upon the consideration of the propositions prepared by the preparatory committee, a summary of which was published in the last number of "Engineering."

In place of Resolution I., "the protection of inventions is to be guaranteed by law in all civilized countries," etc., as proposed by the preparatory committee, which was introduced to the Congress in a long and much applauded speech by Mr. Karl Pieper, C. E., Dresden, dilating on the present state of the patent legislations, supported by statistical data, in America, England, etc., with the patent legislation of which countries that of Prussia contrasted most unfavorably, as being the worst in existence, in practice and application, Dr. William Siemens proposed to adopt the following:

The International Congress may please to declare:

"Patents of inventions with obligatory publications are necessary and indispensable to the preservation and promotion of technical progress, because:

"*a.* They offer the only practicable and effectual means of introducing, without loss of time, and in a satisfactory manner, new ideas and improvements to the general notice of the public.

"*b.* They render the work of the inventor remunerative, and thus induce men of talent to devote their powers, time, and means to the introduction and carrying out of new methods of manufacture and technical improvements, or attract foreign capital, which, without patent protection, would seek and find a safer investment elsewhere.

"*c.* By the obligatory and complete pub-

lication of the invention forming the subject of the patent, the great sacrifices of time and money, which would be otherwise imposed upon the industry of all countries by carrying out inventions, will be considerably diminished.

"*d.* The manufacturer's secrecy, which is the greatest enemy of industrial progress, loses thereby its principal support.

"*e.* The countries which have no good patent laws are injured greatly in consequence of the emigration of their inventive talents to those countries in which their labor and their products are legally protected."

The general debate on this proposition was not without interesting incidents. First, its mover himself, Dr. Werner Siemens, in a very clever speech, explained, in a precise manner, the reasons for maintaining the system of patent protection, which contributed most effectually towards the speedy extension and application of new inventions. It was this protection of inventions which was the death-blow to the secrecy of manufacture, which, through generations, clogged all progress. These remarks drew forth a declaration from the minority—the party opposed to all patents—for whom Professor Dr. Neumann (Vienna) acted as spokesman. He stated that already, ten years ago, he had publicly given utterance to the same views, and he and his friends, though small in number as yet, were of opinion that the principle of liberty, *i.e.*, the principles of free trade, must also be applied to inventions and patents. The latter were incompatible with the progress of our time, with free trade; they were opposed to all principles of liberty, as could be proved by their own history, since they were intended as a compensation for the rights formerly possessed by corporate institutions and guilds.

Dr. Collyer, who had taken his seat in the Congress as the special delegate of the Inventors' Institute of London, complained, in a rather unparliamentary and dramatic manner—which was rendered singularly comical by the entirely uncalled-for vehemence of speech and gesture by which that gentleman introduced himself to the Assembly as the "enfant terrible" of the Congress—that the German should be the official language at the meetings, though it had been settled in the original programme and the standing rules that the members would be at liberty to speak also in either the English, French, or Italian languages, and that all motions, amendments, etc., would be communicated to the meeting in both the German and English languages.

Dr. Collyer, in the same passionate manner, protested against the views enunciated by Dr. Neumann, and advocated the protection of inventions by patents. The debate on the different points of Dr. Siemens' motion, having been adjourned on Monday afternoon till the following morning, was at length concluded bp the adoption by 74 votes against 6, of the following amended resolutions:

"RESOLUTION I.—The protection of inventions is to be guaranteed by the laws of all civilized nations under the condition of a complete publication of the same; because:

"*a.* The sense of right of civilized nations demands the legal protection of intellectual work.

"*b.* This protection affords the only practical and effective means of introducing new technical ideas, without loss of time, and in a reliable manner, to the general knowledge of the public.

"*c.* The protection of invention renders the labor of the inventor remunerative, and induces thereby competent men to devote time and means to the introduction and practical application of new and useful technical methods and improvements, or to attract capital from abroad, which, in the absence of patent protection, will find means of secure investment elsewhere.

"*d.* By the obligatory complete publication of the patented invention, the great sacrifices in time and of money, which the technical application would otherwise impose upon the industry of all countries, will be considerably lessened.

"*e.* By the protection of invention the secrecy of manufacture, which is one of the greatest enemies of industrial progress, will lose its chief support.

"*f.* Great injury will be inflicted upon the countries which have no rational patent laws by the native inventive talent emigrating to more congenial countries, where their labor is legally protected.

"*g.* Experience shows that the holder of a patent will himself make the most effectual exertions for a speedy introduction of his invention."

"RESOLUTION II.—An effective and useful patent must have the following principles:

"*a.* The inventor or his legal heir only

can obtain a patent. A patent cannot be refused to a foreigner.

"*b.* In order to carry out the principle stated above (*a*), the introduction of the system of a preliminary examination is recommended.

"*c.* A patent for an invention should be granted for fifteen years, or the option should be to extend it to that period.

"*d.* The granting of a patent must be accompanied by a detailed and complete publication which renders the practical application of the invention possible.

"*e.* The cost for the granting of a patent should be moderate, but in the interest of the inventor an increasing scale of fees should be fixed so as to cancel an useless patent as soon as possible.

"*f.* It should be easy for any one to obtain through a well-organized patent office, the specifications of any patent, as well as to ascertain which patents are still in force.

"*g.* Laws should be passed by means of which a patentee may be compelled, in cases of public interest, to allow the use of his invention for a suitable remuneration to all *bona fide* applicants."

For the rest, and especially with respect to the proceedings in the granting of patents, the Congress refers to the English, American, and Belgian patent laws, and to the proposition made by the Union of German engineers for a patent law of the German empire.

"Resolution III.—In consideration of the great difference between the existing patent laws, and in consideration of the altered state of international communication, the necessity of reform becomes evident, and it is to be strongly recommended that thedifferent Governments should endeavor to arrange, as soon as possible, an international understanding on the patent laws.

"The not executing of a patent in a country is no reason for its becoming void in that country, as long as the invention has been carried out once, and the possibility is there that the right of using the invention can be obtained by any inhabitant of this country."

At the closing of the Congress the committee was constituted as a permanent executive committee, with the power to publish the resolutions adopted, and to submit them to the various Governments. The committee is also authorized to choose members, and to prepare and convoke in a suitable manner a second Congress.

On Saturday, the 9th of August, the president and members of the Council of the Patent Congress, were introduced by Baron Schwarz to the two ministers in the Austrian Empire, to the department of which the resolutions of the Congress belong, and by which they have to be sanctioned before any practical results could be expected from the meeting of the first Patent Congress.

The committee was at first received by Dr. Banhans, the president of the Board of Trade, and afterwards by Count Andrassy, Minister for Foreign Affairs. Both Dr. Banhans and Count Andrassy received the deputation in the most courteous manner, and expressed the great interest they took in the question brought under their consideration by the Congress, and promising to take the resolutions adopted into full consideration. Count Andrassy promised to use his influence that Austria should take the initiative for an international conference on the discussion and adaptation of a general patent. During the interview Mr. Q. C., of London, and Mr. Thacher, of the American Patent Office, explained to Count Andrassy the working of the English and American patent laws.

ERIE RAILWAY SPECIFICATIONS FOR IRON BRIDGES.

From "The Railroad Gazette."

The Erie Railway Company has recently invited proposals for the construction of a large number of iron bridges. The following are the specifications:

LOADS.

Bridges are to be proportioned for the following weights, in addition to the weight of iron in the trusses and iron floor beams:

For a floor weighing 400 lbs. to the lineal foot for each track.

For a moving load varying from 1,500 to 3,500 lbs. for each lineal foot of truss, ac-

cording to the following table, these weights being by the foot of each truss and not of each track.

Length of Span.	Each truss of single-track bridges and outside truss of 3-truss double-track through bridges.	Each truss of 2-truss double-track through bridges and centre truss of 3-truss double-track through bridges.	Each truss of 2-truss double-track deck bridges.	Each truss of 3-truss double-track deck bridges.
Fifty feet and under.	2,000	3,500	4,000	2,500
Over 50 and not over 100 feet.....	1,750	3,000	3,500	2,250
Over 100 and not over 150 feet.....	1,500	2,750	3,000	2,000
Over 150 and not over 200 feet.....	1,500	2,500	2,750	1,750

Strain sheets are to be furnished for the examination of the Engineer of the Erie Railway Company.

BOILER-PLATE GIRDERS.

Boiler-plate girders will generally be used for spans of 50 ft. and under. The iron in the lower rib shall not be strained to exceed 10,000 lbs. to the square inch of section, after a full allowance shall have been made for rivet holes. The iron in the upper rib shall not be strained in compression more than 7,500 lbs. to the square inch of section. Three-quarter inch rivets shall be used with a 6 in. pitch. The web plates shall be from $\frac{1}{4}$ to $\frac{1}{2}$ in. thick, according to the following table:

Span.	Each girder of single-track bridge and outside girder of 3-truss double-track through bridges.	Each girder of 2-truss double-track bridges and middle girder of 3-truss double-track through bridges.	Each girder of 3-truss double - track deck bridges.
35 ft. and under..	$\frac{1}{4}$ in. plate	$\frac{5}{16}$ in. plate	5-16 in. plate
Over 35 ft.....	$\frac{5}{16}$ do.	$\frac{1}{2}$ do.	$\frac{3}{8}$ do.

There shall be vertical stiffeners of T iron on each side not more than 4 ft. apart, which shall be bent over and riveted to the top and bottom rib plates. Deck bridges shall have lateral bracing both above and below, and shall have diagonal vibration ties at least every 10 ft. Through bridges shall have lateral braces at the bottom, and be stiffened by knee braces and gusset plates not more than 10 ft. apart, which shall attach to the girders at the vertical stiffeners.

In single-track deck bridges, two girders will be used, placed 8 ft. between centres. In double-track deck bridges, two girders will be used, placed 16 ft. between centres, or three girders placed 10 ft. between centres.

In single-track through bridges, two girders, and in double-track through bridges, three girders will be used. If not more than 3 ft. 6 in. deep, the girders shall be placed 13 ft. between centres, if more than 3 ft. 6 in. deep, 13 ft. apart in the clear.

The timber floor will rest upon the top of the girders in deck bridges, and on the inside of the lower rib plates of through bridges unless otherwise specially directed.

TRUSS BRIDGES.

For spans of over 50 ft., truss bridges will be used. Unless otherwise specified, the form of truss shall be selected by the builder; but to secure uniformity in appearance and character, it is desired that all through trusses be built with inclined end posts, and a preference will be had for bridges built with pin connections.

In single-track through bridges and in double-track through bridges with three trusses, the trusses shall be placed 15 ft. apart in the clear, and in double-track through bridges with two trusses they shall be placed 28 ft. apart in the clear. There shall be a clear head room of 19 ft. above the rails. In single-track deck bridges the trusses shall be placed 12 ft. between centres, in double-track two-truss deck bridges 16 ft. or more between centres, and in double-track three-truss bridges 10 ft. between centres.

Pony trusses shall be stayed by wind braces at every floor beam, these braces extending at least to the middle of the posts.

All tensile members shall be of double-rolled refined wrought iron of soft, fibrous texture, with an ultimate strength of 55,000 to 60,000 lbs. per square inch, which shall not take a permanent set under a strain of less than 23,000 lbs. per square inch, and shall elongate at least ten per cent. before

breaking. Each bar containing a weld shall be tested to a strain of 20,000 lbs. per square inch, and the perfection of the weld established by striking the bar while under strain or by carefully measuring its elongation. If upset bars are used, the method of their manufacture must be approved by the Chief Engineer of the Erie Railway Company. No tensile member shall be subjected to a strain exceeding 10,000 lbs. to the square inch under the assumed maximum load.

Floor suspenders carrying but a single panel length of 12 ft. or less shall have a section of 4 sq. in. in each truss of single-track bridges, and in the outside trusses of three-truss double-track bridges; and a section of 7 in. in the middle truss of three-truss double-track bridges, and in each truss of two-truss double-track bridges; for panels more than 12 ft. long the section shall be proportionately increased.

Compression members shall be of wrought iron; when the least dimension is not less than one-twelfth the length of the member, the iron may be subjected to a strain not exceeding 8,000 lbs. per square inch of section; when the least dimension is less than one-twelfth the length of the member, the strength of the member shall be determined by Gordon's formula, and it shall be proportioned with a factor of safety of 5.

Pins shall be of wrought iron, and shall be turned to fit the pin-holes within $\frac{1}{32}$ of an inch. The section of the pin shall be such that the shearing strain on such section shall not exceed 6,000 lbs. per square inch, and the diameter of the pin shall not be less than two-thirds the largest dimension of any tension member attaching to it. The several members attaching to the pin shall be packed close together, all vacant spaces being filled with washers. The lower chord shall be packed as narrow as possible, and the several parts must be so arranged as to produce no appreciable bending strain upon the pin. The effective length of the pin shall not be greater than the breadth of the foot of the post plus four times the diameter of the pin.

Special pains shall always be taken in drilling the pin holes, both in accuracy of fit and in exactness of length; and if the difference of length is such in several bars which are to be placed side by side, that when they are piled on each other, all being of the same temperature, both the pins will not pass through their holes at the same time without driving, the set shall be rejected. The full sections of all members, whether in trusses or laterals, shall be kept up at the connections. The enlarged end of the eye bars shall have a connection outside of the pin hole one-fifth greater than the body of the bar.

The lateral braces shall, whenever practicable, be attached to the chords in such manner that the axis of each lateral strut shall coincide with the axes of the pins. The dimensions of the lateral rods shall be equivalent to the following:

Spans.	Upper laterals in deck bridges, lower laterals in through bridges.	Lower lateral deck and upper laterals in through bridges.
50 ft. and under.....	1 in. round in.	⅞ in. round.
Over 50 and not over 100 ft.....	1⅛ in. round in.	1 in. round.
Over 100 and not over 150 ft.....	1¼ in. round in.	1¼ in. round.
Over 150 ft.....	1⅜ in. round in.	1¼ in. round.

The lateral struts shall have a section of equivalent strength. In double-track two-truss through bridges, each top lateral rod shall reach across two panels passing through a strut at the middle of the bridge, and a stiffening strut running along the axis of the bridge shall connect the centres of the several lateral struts. Deck bridges shall have diagonal wind ties, of the same dimensions as the bottom lateral ties in single-track bridges, and as the top lateral ties in double-track bridges.

No wrought iron shall be used less than three-eighths inch thick, except in places where both sides are always accessible for cleaning and painting.

Cast iron may be used in bed plates, pedestals and washers, but never in any position where it is liable to receive a transverse or tensile strain. It shall be the best quality of soft gray iron.

FLOOR.

In deck bridges the floor will be formed of timber floor beams 12 to 15 in. deep and 18 in. between centres, on which the rails shall be laid; these beams shall rest directly upon the upper chords, which shall be proportioned to carry a load of 5,000

lbs. to the foot for each track between the points of support, in addition to the compressive strain to which they are otherwise subjected. In double-track two-truss deck bridges each timber floor beam shall be bolted to each truss with a bolt of 1 in. round iron.

In single-track through bridges a longitudinal iron floor beam shall be placed in the centre of each chord, each beam proportioned for a moving load of 2,500 lbs. per running foot. These longitudinal floor beams will carry timber floor beams 8 in. by 15 in., placed 2 ft. between centres, on which the rails are laid.

In double-track two-truss through bridges there shall be a transverse iron floor beam suspended to the pin at each post by suspenders each having a section of 7 in. for panels of a length of 12 ft. or less; for longer panels the section of the suspender shall be proportionably enlarged. Three longitudinal floor beams of iron, placed 13 ft. between centres, shall connect the transverse floor beams, being rigidly attached to them, on which shall be laid timber floor beams 12 in. deep to carry the track; the top of the longitudinal floor beams shall not be more than 11 in. below the top of the transverse iron beams, and they shall be kept as low as possible without projecting below the transverse beams. The outside longitudinals shall be proportioned for a rolling load of 2,500 lbs. per foot, and the inside beam for a rolling load of 4,500 lbs. per foot, and the transverse beams for the results of these weights at the three points of application; factor of safety 6. The parallelograms formed by the iron floor beams shall be braced by diagonal ties of the sizes given in the table of lateral rods, and this shall be the only lateral bracing of the bottom chords.

BEARINGS, ETC.

All trusses shall rest upon cast-iron bed plates placed upon the masonry, and shall have sets of rollers under one end.

In through bridges, knee braces of wrought-iron shall connect the end posts with the end lateral struts. The portals at the end of each bridge shall be finished with an ornamental casting, the pattern for which shall be furnished by the Erie Railway Company, though the contractor will be required to make such alterations as are necessary to fit the pattern to the details of the bridge.

HYDRAULIC GUNNERY.

From "The Engineer."

Sir W. Armstrong has recently fitted a gunboat for the Dutch Government with hydraulic machinery for working the single heavy cannon which the little craft mounts. It appears that Major Moncrieff schemed an arrangement by which the gun when fired would by its recoil compress air by the aid of water in a cylinder; and the air so compressed was intended to act as a motive power to assist in raising the gun to the proper position for firing. This scheme is said to have failed; and the mechanism used by Sir Wm. Armstrong depends for its efficiency on the working of an acumulator, the recoil of the gun not being utilized in any way. The publication of these facts has called attention to the working of guns by hydraulic power; and there are many points of interest connected with the subject which deserve notice.

There are three distinct ways in which water or some other liquid, such as oil, can be used in working heavy ordnance. In the first place we have the hydraulic compressor. The gun in recoiling actuates a piston moving in a cylinder partially filled with water or oil. The liquid can only escape from one side of the piston to the other through a small orifice, and the whole force of the recoil is expended in forcing the water or oil through this orifice, and in generating heat in the liquid compressed, and in the air which must always be present in the cylinder. If the cylinder were quite full of water, the gun would practically have no recoil, because of the inelasticity and inertia of the water; the air in the upper part of the cylinder, however, acts as an excellent spring. The piston is driven back by the force of the recoil, and the air is compressed. It expands again after the recoil is over, driving the water through the orifice in the piston. This arrangement works, on the whole, moderately well, but it cannot be looked upon as a perfectly satisfactory arrange-

ment for taking up recoil. A second method of using hydraulic power in working guns is that which has been practically brought to perfection by Mr. Holman, a member of the firm of Tangye and Co. In another page we have illustrated this arrangement as applied to the 35-ton guns of the Devastation. The water is used in small jacks, and by their aid the gun can be raised and lowered in its carriage; but the fluid in this way takes no active part in the working of the gun, that is to say, in the operations of loading, firing, and training it. The third method, of calling in the aid of hydraulic power, finds one illustration in the designs of Sir W. Armstrong and Co., as carried out in the Hydra, and as this is the most important way of using water or oil in connection with artillery, it is to this that we shall at present devote our attention.

The work to be done on a gun may be classed under three heads. It has to be run out and fired, and then run in and loaded; secondly, it has to be trained round in a portion of the arc of a circle; thirdly, the gun may be caused to rise and fall in a pit or behind a screen. The first operation we have named is generally effected by utilizing a portion of the force of the recoil by making the gun on running in ascend a moderately steep inclined plane. When loaded the compressors—really brakes—are taken off, and the gun will then nearly run out by its own weight; it will certainly run out by the application of a very moderate force assisting it to move. The inclined slide, therefore, represents one mode of utilizing recoil. The use of hydraulic power in training a gun has hardly yet been effected, although it is obvious that water-pressure engines can be employed to rotate a turret, or that a curved ram working in a curved cylinder might be easily applied to move the trail end of a gun-carriage right or left on the racers. All such applications of hydraulic power appear to be likely to prove eminently useful when we have to deal with very heavy guns. But it is in carrying out the schemes of inventors who now seek to effect the bodily rise and fall of the gun, that hydraulic power will prove most useful. Nine years have elapsed now since Major Moncrieff first proposed that a heavy gun in recoiling should at the same time descend into a pit, where those working the weapon would be comparatively safe from an enemy's fire; and he has worked at this idea with varying fortune and much persistency. As to the final result at which he has arrived, opinions differ. Many intelligent and experienced artillerists pronounce the Moncrieff system a complete success, others award it moderate praise, and not a few assert that although the idea is good it has not yet been reduced successfully to practice; and these gentlemen apparently have some foundation for their statements, as, although there are large numbers of Moncrieff pits in existence, we cannot call to mind at this moment the name of any important battery in which a non-experimental Moncrieff gun carriage is fitted complete. Two points present themselves for discussion in considering the merits of the system. Firstly, are the mechanical appliances for working guns in pits satisfactory? Secondly, is the principle satisfactory in itself? On the first point we shall add nothing to what we have already said. On the second, opinions vary, some officers asserting that by the aid of rifled mortars Moncrieff pits would be rendered shambles, and we confess that we are rather disposed to agree with those gentlemen. At the battle of Woerth about 700 men were killed in one large French rifle pit or trench in the course of a few hours' fighting, and nearly all these men were killed by Prussian shells. The Moncrieff system, it may be well here to explain, consists, not in placing guns in pits, from which they are to be lifted in order to be fired, by hydraulic or any other power, but in storing up the work done by the recoil of the gun for future service in lifting the gun up; the use of guns in pits may be taken as an accident of the system—it is not essential to Major Moncrieff's invention. But Major Moncrieff works with a balance-weight, and this has nothing to do with hydraulic gunnery; therefore, were it not that the inventor has proposed to use compressed air and water in lieu of a balance-weight, a reference to his system would hardly be needed at all in this article. It is well that the true nature of the Moncrieff system should be understood. If it be not, many inventors will come forward and claim as theirs what is not theirs. For example, there is nothing novel in proposing to use water power for raising and lowering guns behind a parapet, or in or out of a pit; but Major Moncrieff invented a new thing when he

proposed to store up the recoil of a gun for this purpose. There is reason to think, from the results of Sir William Armstrong & Company's experience, that there are better ways of applying hydraulic mechanism—at all events to the raising and lowering of guns—than any which depend on the recoil as a motive power.

A very ingenious method of working heavy guns by hydraulic power was proposed about nine years ago by a Mr. Walker, of the City-road. Each gun was to be mounted on a species of turn-table carried on the upper end of a hydraulic ram. Two ram cylinders being put in communication by a suitable pipe, it is obvious that one gun would balance the other. A very small steam pump, by transferring the water from one cylinder to the other, would cause one gun to descend after being fired, and the other to ascend to be fired. The loading would take place behind a suitable breastwork, either in a land fortification or on board a ship. Much the same idea was patented about the same time by Mr. Winans in the United States. The use of a water balance in this way presents many excellent points, provided it be admitted that it is a good thing to fire guns over breastworks or out of pits, and this involves questions on which we prefer to reserve an expression of opinion excepting as regards gunboats, and for gunboats we have no hesitation in saying that nothing better than a rising and a falling gun can be desired. It is questionable, however, whether the use of an accumulator in the ordinary sense of the word is desirable, or whether the use of a pumping engine is necessary. In the boilers of gunboats steam having a pressure of 60 lbs. to the square inch is available; and there does not appear to be any good reason why the pressure of steam should not be used direct to supply all the power required to work, say, a 10-ton gun. Taking the gross weight of such a weapon with its carriage, etc., at 15 tons—which is over the mark—and suppressing altogether the utilization of the recoil, we find that a ram with an area of 560, or say 600 sq. in., will, with a pressure of 60 lbs. on the sq. in., suffice to lift the gun with ease and rapidity; in other words, a ram, or probably a piston, would be more convenient—a little over 2 ft. in diameter would suffice. The pressure would be obtained by admitting steam above the surface of water in a vessel answering to an accumulator. When the steam was suffered to escape, the water would return to the vessel and the gun would descend. Such an arrangement would at once get rid of much complicated mechanism. Of course, if what remained were damaged by shot, the gun might be rendered *hors de combat;* but this is a defect common to all schemes for raising and lowering guns and firing them over breastworks. The officer in command is always liable to see his gun, in other respects quite serviceable, lying safely stowed away at the bottom of a pit from which he has no means of lifting it up.

REPORTS OF ENGINEERS' SOCIETIES.

THE IRON AND STEEL INSTITUTE of Great Britain convened at Liege on the 18th of August.

Among the papers presented were: The rise and progress of the Iron and Steel Industries in Belgium, by Julien Derby, C. E.

The rationale of the combustion of gases considered in relation to an increased supply of heat, by Chas. Boutney.

On Buttgenbach's system of Blast Furnaces, by Franz Buttgenbach.

The economical preparation of Iron for the Danks Puddling furnace, by Chas. Wood.

On Winding Machinery, by Wm. Kamp.

On improvements in the construction of metalways, by M. Soignie.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—At a regular meeting of the Society held July 2d, 1873, was presented the following:

As set forth in the Constitution, two of the objects of the American Society of Civil Engineers are: the professional improvement of its members, and the advancement of engineering in all its branches.

Among the means whereby these objects are to be secured, are: the collection and dissemination of current professional knowledge, and the foundation of a library and museum.

The professional improvement of members comprehends the collection and distribution among them, of all experimental knowledge relating to their profession, both of the past, finished and recorded, and of the present, incomplete and unwritten. This includes the discussion of theory, the results of practice, the accounts of success and failure, the teachings of experiment, and the examination of data; and thus will largely promote the advancement of engineering in all its branches.

At best the purpose of the Society will be but partially effected by the collection and dissemination of current professional knowledge, unless the same is also securely preserved; this involves the foundation of a library and museum.

The library of the American Society of Civil Engineers should contain all that has been published relating to the history and prosecution of engineering, maps and profiles of every canal and

railroad, their complete reports, those of the several Municipal, State and Federal departments, and select published matter referring to other and miscellaneous works, public and private. It should also contain standard works of reference in science and art, and indeed lack nothing of a library by the student or accomplished engineer seeking professional knowledge. The museum should be an adjunct of the library, and illustrate in matter much that is there described in words; efficiently representing by models and samples, the proportions, form and physical characteristics of the agents of engineering effort.

Much professional knowledge is recorded in the several technical journals of the day, and this is almost inaccessible to the busy members of a profession which allows but little time or opportunity for exhaustive reading. Complete treatises are published from time to time, upon theoretical or practical subjects, full of matter valuable to engineers who are unable to possess or peruse them. These, as issued, should form a part of the library of this Society, and be made available to members.

The advantages of such a library should be placed at the command of all connected therewith, wherever they may happen to reside, so that, on request, complete examinations upon specified topics could be made, pertinent extracts copied, and proper references given; therefore—

Whereas, the foundation of a library and museum, which contains within itself all accessible published matter relating to the history, theory and practice of engineering, the construction and management of public improvements, and the methods and cost of manufacturing operations, with illustrations, by models and samples, of the results thereby obtained, must be invaluable, not only to the profession, but to all who are interested in the pursuit or the application of practical knowledge.

Resolved, That a Committee, consisting of the President and nine other members to be named by him, with power to fill vacancies, be appointed to devise a plan whereby such a library and museum may be founded; the funds obtained for its collection, management, increase and maintenance, a suitable place secured, where it and other possessions of the Society may be preserved, and its advantages enjoyed by members and others connected therewith, irrespective of their location; the Committee to report to this Society before October 1st, next; the report to be printed and distributed to members for examination and approval, and action thereon made a special order for the annual meeting, to be held November 5th, 1873.

The resolutions were adopted.

A CABLE dispatch announces that the British Iron and Steel Institute, at its meeting in Liege, resolved to hold its next annual meeting in this country, and selected Philadelphia as the place. This is the answer of the most important body of Englishmen interested in the great problems of the iron trade, to the invitation of our Institute of Mining Engineers. The fact is matter for no small congratulation. England contains more men in whom iron workers the world over are interested than all the other countries, and a year from now we shall see Philadelphia filled with men curious to see, and anxious to speak with, those whom we all acknowledge to be masters in our calling. Pity that we cannot persuade Tunner, Gruner, Ackerman, Buttgenbach, Funck and the other studious and experienced metallurgists of the Continent to pay us a visit at the same time. Though they come here to study us, we can make their visit something more than a social meeting. The literature of the profession is almost altogether in their hands, and we shall find a more personal interest and a greater confidence in it when we have seen its authors face to face.

IRON AND STEEL NOTES.

ORIGIN OF THE PUDDLING PROCESS.—Davy investigated the nature of the flame, and communicated his discoveries in a lecture before a large audience. He demonstrated that it was within our power to produce a flame which, at a state of extreme heat, contained either free oxygen or unburnt carbon; that a large grate with a limited supply of coal would generate the former, the oxidizing flame, while a small grate with a larger amount of coal would yield the other, the flame devoid of oxygen, but in which combustible substances might be melted without the danger of combustion. Among the hearers sat a young man by the name of Cort, who directed his mind to these remarks. Up to that time cast iron was converted into wrought iron by heating it with charcoal and exposing the melted metal to a blast of air. By this process only small quantities of wrought iron were obtained at a time, through the necessity of producing but one bloom in a heat, which might easily be hammered out; and also on account of the cost of charcoal. In this process, mineral coal could not be placed in contact with the iron, because the never-failing presence of sulphur in that kind of coal would render the iron unfit for use. From Davy's lecture on the flame, Cort struck upon the idea of decarbonizing cast iron without exposing it to the danger of the contact with coal, by allowing the flames only of the coal to play upon the cast iron. Thus originated that wonderful operation called the puddling process.—*Mohr*.

CHICAGO is now manufacturing railroad iron at a rate of 80,000 tons per year. This branch of industry will undoubtedly become one of the most important interests of that city.

NEW JERSEY iron is now used by an extensive company in making sewing machines, instead of the British product known as Low Moor iron, which it previously employed.

BESSEMER STEEL.—AN EXPERIMENT IN TROY.—In February, 1872, at the instance of Mr. Holley, and under the direction of Dr. Adolph Schmidt, the Messrs. Griswold very liberally gave my plan for the substitution of a cheaper material for spiegeleisen a fair trial. This method was the use of silicon instead of manganese, for the purpose of reducing the oxides formed in the last stage of the American and English processes of "overblowing." The idea was based upon the greater affinity of silicon for oxygen than iron for that element, and as affinity is so dependent upon temperature, actual experiment was necessary to determine its value. The following were among the results obtained in the two-ton converter:

Charge, 1899; recarburized with 5.3 per cent. spiegel and franklinite and 1.3 per cent. Poughkeepsie iron—6.6. Grade III½; ingots rolled well.

Charge, 1913; recarburized with 2.6 per cent. Poughkeepsie iron and 4.0 per cent. spiegel and franklinite—6.6. Grade III¾; ingots rolled pretty well.

Charge, 1925; recarburized with 4.0 per cent. Poughkeepsie iron, 1.3 per cent. spiegel, and 1.3 per cent. franklinite—6.6. Grade III; ingots cracked in rolling.

Charge, 1965; recarburized with 2.6 per cent. Durham iron, 2.0 per cent. spiegel, and 2.0 per cent. franklinite—6.6. Grade III¼; ingots rolled well.

Poughkeepsie iron is an anthracite iron used at that time in small quantities with Cumberland iron in the charge for steel. It contained considerable silicon. Durham iron was made from the pure and highly silicious magnetic ore of Cooper & Hewett, at their furnace in Durham, Pa. The minimum of silicon which they have been enabled to obtain by basic changes and comparatively cold blast, was 5.30 per cent. Unfortunately there were no analyses made of the cracking ingots, to determine the cause of their red shortness, whether due to silicon or unreduced oxides. As in the presence of manganese, silicon would doubtless be inert, it is important to know the minimum amount of manganese, and hence of spiegeleisen, to perform the work of reduction. As steel would bear less of silicon than of manganese, it would be more difficult to adjust the necessary amount to recarburize than of spiegeleisen. The grade marks are in accordance with Dr. Schmidt's forge test classification, based upon the hardness and angle of fracture of an annealed and tempered piece of the steel, square and about ⅛ sq. in. section. Grade III corresponds to about ¼ to 0.3 per cent. of carbon, and is preferred by the railway companies. Will spiegeleisen always be available, and if not, are we to recur to the Continental method of fixed converters and under blowing, or, are we to find a substitute?—*American Manufacturer.*

RAILWAY NOTES.

DYNAMOMETER USED ON THE PHILADELPHIA & READING RAILROAD.—We give this week a lithograph of a dynamometer used on the Reading Railroad. The spring is made in four sections with five spring plates in each. The spring plates are made of ⅜ in. steel, 24 in. long by 4 in. wide in the centre and 1¼ in. at the ends, and are kept separated by distance pieces to avoid friction. In graduating the instrument only one section at a time is put in place, and weights of 1,000 lbs. each are applied. The deflection is then noted until it is loaded with 10,000 lbs. The instrument is very simple, and more delicate and reliable than any other form which we have thus far seen.—*Railroad Gazette.*

RAILWAY EARNINGS FOR MAY.—A summary of the earnings by the more important of our railways for the past month as compared with the same period last year, shows a net increase of $655,980, although on six of the railways taken into the account there has been a falling off,—in all of $136,510. Still the large gains of many companies under circumstances which hardly warranted the expectation, renders the outlook highly encouraging. Twenty of our principal railways show the following gross earning for May, both years:

	1873.	1872.
Atlantic & Great Western	$428.524	$435,534
Atlantic & Pacific	112,275	80,759
Bur., Cedar Rap. & Minn.	82,682	66,725
Chicago & Alton	426,315	440,457
Chicago & Northwestern.	1,237,083	1,074,779
Cleve., Col., Cin. & Ind.	394,485	378,493
Erie	1,754,421	1,729,218
Illinois Central	554,935	636,378
Ind., Bloom. & Western	133,758	125,287
Kansas Pacific	332,763	334,285
Lake Shore & Mich. Sou.	1,680,968	1,474,467
Marietta & Cincinnati	185,683	160,818
Milwaukee & St. Paul	805,799	580,432
Ohio & Mississippi	310,785	283,371
Pacific & Missouri	301,521	269,959
St. Louis, Alton & T. H.	118,422	109,422
Do. do. branches	45,878	38,030
St. Louis, Kan. City & No.	57,847	59,010
St. Louis & Southeastern	64,480	....
Toledo, Wab. & Western.	489,557	510,792
Total	$9,508,581	$8,788,121
Net increase 1873	655,980	....

The Central Pacific's statement has not been received, but the gains are undoubtedly well maintained, as heretofore. The total earnings since January 1st show a handsome advance over the same period the previous year. The earnings of nineteen railways (St. Louis & Southeastern excepted) for the past five months amounted to $42,369,153, against $38,148,619, showing a gain of $3,745,838.—*Chicago Railway Review.*

THE NORTHERN PACIFIC.—General Rosser, the engineer in charge of the surveys, has submitted his official report to the Company. He finds the new and final route across Western Dakota, from the Missouri to the Yellowstone river, entirely practicable and satisfactory, it being greatly superior to those of former surveys. The distance, 205 miles, is 21 miles shorter than the survey of 1871. The grades are moderate. The average of work per mile is considerably less, and the number of important bridges is reduced nearly two-thirds. The Little Missouri river, which former surveys crossed seven and eleven times, is crossed once. On the line so located the route runs immediately through only one mile of bad clay lands, just east of the Little Missouri. With few exceptions the country is a rolling prairie, sometimes rising into low hills, the grass being excellent and the soil good. Good water was found the entire distance. Coal outcrops at various points in veins several feet in thickness, and timber is more abundant than on former routes. The report states that the main body of General Stanley's expedition, and most of the press correspondents, accompanied the scientific corps, and did not accompany the engineers. The former were

escorted by General Custer's detachment, and followed the old, abandoned route south of Heart River; hence descriptions of the region traversed by the main command do not apply to the country traversed by the new route nor the railroad.

The Directors of the Company have accepted the new line recommended by General Rosser, from Bismarck, the present end of the track, to the Yellowstone crossing. The Company advertises for sealed proposals for grading and bridging the line from Bismarck to the Yellowstone river, 205 miles. Proposals will be received for the whole distance or for sections of about 25 miles each. Information as to the line, etc., can be obtained at the office of W. Milnor Roberts, Chief Engineer, No. 23 Fifth avenue, New York, or from General T. L. Rosser, Division Engineer, at Minneapolis, Minn. Proposals will be received at the office of the Chief Engineer, up to September 10.

The expedition is now prosecuting its survey westward up the left bank of the Yellowstone to Pompey's Pillar, where it will join the survey made last year from the west, and thus complete the surveyed line across the continent. The entire command is expected to return to Fort Rice about October 1st.—*American Manufacturer.*

RECORD OF NEW RAILROAD CONSTRUCTION.—The "Railroad Gazette" of Sept. 6th has information of the laying of track on new railroads as follows:

Springfield, Athol & Northeastern.—Extended from Barrett's southwestward 10 miles to Indian Orchard, Mass. Selma, Marion & Memphis.—Extended from Greensboro' west 8 miles to Sawyer's, Ala. Southern Pacific.—The Hollister Branch has been extended from Hollister southward 6 miles to Tres Pinos, Cal. Ware River.—Extended from Barre Plains, Mass., northward 9 miles. Cleveland, Mount Vernon & Delaware.—Completed by the extension from Sunbury southwestward 22 miles to Columbus, Ohio. Cairo & Fulton.—Extended from Little Missouri River southwest 33 miles to Fulton, Ark. Pennsylvania.—New York Division.—The line in Jersey City to Harsimus Cove, 1¼ miles, is completed. Atlanta & Richmond Air Line.—Completed by the laying of track for 69 miles from a point 86 miles northeast of Atlanta, Ga., east by north to the Saluda River, S. C.

This is a total of 158¼ miles of new railroad, making the mileage completed in the United States in 1873, 2,284 miles.

EASTERN OF FRANCE RAILWAY.—The Eastern of France Railway Company owned at the close of last year 905 locomotives, 796 tenders, 2,386 passenger carriages, 22,036 goods trucks and wagons of various kinds. The company is now constructing 6 locomotives, 5 passenger cariages, and 30 good trucks, which will be delivered in the course of 1872. These orders have been given out with a view to the replacement of material destroyed during the Franco-German war. The company has sold for £8000 to the Turkey in Europe Railway Company its "Imperial train;" this step was decided on as the maintenance of the State carriages involved considerable expense. It will be remembered that this "Imperial train" conveyed Napoleon III. and his chief officers to the scene of war in August, 1870. The Eastern of France Railway Company has for some time past completed the last section of the Rheims and Metz Railway, viz., that from Verdun to Metz. Difficulties have, however, arisen in regard to the ballasting the new line, the old supplies of ballast being exhausted. Sand is being dredged out of the Meuse and applied to ballasting purposes.

RIO PRETO (BRAZIL) RAILWAY.—The statutes of the Rio Preto Railway Company have been approved by the Brazilian Government. The company proposes to construct a narrow gauge line from Barra do Pirahy to Rio Preto, by way of Ipiabao and Conservatorio. The cost of the line is estimated at 2,000,000 milreis.

ENGINEERING STRUCTURES.

THE NEW PESTH BRIDGE.—The works of the new bridge across the Danube at Pesth have been commenced, and are now being actively pushed forward. It will be remembered that this work was awarded to Messrs. Ernest Gouin and Co., of Paris, on the occasion of the International competition.

The Danube at the site of the bridge is divided into two channels, separated by a small island called L'Ile Marguerite. The bridge will establish comunication between the two sides of the river and this island. The design shown is divided into five spans, of which two are on the smaller branch, and three on the greater.

The span of the arches are, approximately, 278 ft. for the two land spans, 305 ft. for the openings across the main branch, and 321 ft. for the main span of the smaller arm. The bridge has a width of 49 ft., of which 31 ft. is devoted to the carriageway, and 9 ft. to each of the foot-paths. The arches spring at a height of 32 ft. above water level on the piers, and 25 ft. above that level on the abutments. The foundations of piers and abutments are in masonry; they are to be executed with iron caissons, sunk by compressed air to the level of the blue clay. The average depth of the foundations in the clay will be 3 ft., giving them a total depth of 32 ft. The ends of the pier caissons will be semicircular, and the pier abutment on the island, as well as those of Buda and Pesth, will form a parallelogram in plan. The river piers are in masonry; from the foundation level to the springing of the arches they are rectangular in plan, terminating at each end in curved cutwaters, and enriched with mouldings towards the high-water level.

Above springings the piers are rectangular up to the road level; a stone parapet surmounts the cornice, which is carried on carved cantilevers. The general decorations are clearly shown in the drawings.

All parts exposed to the action of the water are in granite. The central pier is of the form shown in the drawings, a form rendered necessary by the local conditions of the site.

The superstructure is composed of iron arches, carrying the roadway, which is to be paved with wood; these arches are cellular in section with double vertical sides; to obtain greater stiffness they are connected transversely by a complete

system of cross bracing. The longitudinal girders are also cellular, of a similar form of construction to the arches. The spandrels are filled by cross bars, intersected by vertical standards transmitting the strain from the longitudinal girders to the arches; the vertical faces of the spandrels are filled in with ornamental castings.

The arches spring from cast-iron foundation plates resting on the piers, and of sufficient size to distribute the weight over the area of the pier. These plates are of course furnished with skew-backs upon which the ends of the arched girders abut.

Considerable alterations will be made in carrying out the design; the projected line of works for improving the course of the Danube has been modified in such a manner that the island will be in the middle of the river, so that the bridge, the total length of which has been increased, would be composed of two equal lengths, one across each arm of the stream, and divided each into other spans, of an average opening of 262 ft. each. The length of the bridge has been increased by 55 ft. The direction of the works is intrusted to M. Hainssellin, the Engineer, well known from the great works he has executed in Russia and in France. The ironwork is being made at the establishment of Messrs. Gouin, Batignolles, Paris. —*Engineering*.

NEW DEEP-WATER HARBOR AT BOULOGNE. —There is at last a prospect that a deep-water harbor will be constructed at the other side of the Channel, and this would at once solve most of the difficulties connected with efficient Continental communication. A company has been formed, known as the Boulogne Harbor Company, to carry out the designs of M. Legros, a French engineer, and Mr. Liddell, engineer of the South-Eastern Railway. The new harbor will consist of two stone piers running out from the shore at Chatillon to the south-west of the present harbor of Boulogne. The eastern pier, which will be 984 yards long from the present line of low-water mark, will run in a north-west direction from just beyond the house of M. Huguet, present Mayor of Boulogne, a castellated building with a tower to the west of Capecure pier, which is familiar to all travellers who use the Boulogne route; the second, or western pier, will start from a point 765 yards further west, this pier will be 1,694 yards long; for a distance of 1,000 metres it will run north-west, after that it will gradually assume a course north by west, thus completely sheltering and overlooking the eastern jetty; the space between the two piers for a distance of 383 yards will be filled up to a level of the piers, and form a space for the construction of warehouses. The east jetty, for two-thirds of its length, will have a width of 40 metres, and for the remaining third it will have a width of 80 metres, with a double line of rails running its entire length. At the end the east jetty will have a stone head or jetty, running crosswise, extending 80 metres west and 120 metres east. These horns will form a shelter for the steamers, which may land or embark passengers on either side of this pier, according to the wind, in perfectly calm water. One thousend metres along the west jetty, and in a line with the head of the east jetty, a jetty or horn, 200 metres long, will run in an easterly direction towards the west horn of the east jetty; the space between these two horns, 100 metres, will form the entrance to the new harbor, which will have a depth varying from 10 to 29 ft. at low water, but which, by dredging, will be increased to not less than 18 ft. in its shallowest part. The head of the west jetty will have a depth of 60 ft. around it. The jetties will be of solid stone part of their length, and on open arches the rest of their extent; this construction being much in favor with French engineers, who maintain that by allowing free passage to the currents all silting up by sand is avoided. This harbor will be capable of receiving the largest and swiftest steamers which can be built, whether on the Bessemer or any other principle; it will also form a harbor of refuge, for want of which several vessels are annually lost on this coast, more especially at low water, when distressed vessels are unable to get into the present small harbors, oftentimes difficult of access even at high water. It will require five years to construct this harbor, but the engineers hope that three years will suffice to advance the works sufficiently for large steamers to commence running.

THE SIERRA MADRE TUNNEL.—The commencement of this entenprise has created less noise than one would expect from such a huge undertaking. Yet, if it should be only partially successful, not reaching the other side of the range for years to come, the tunnel promises to become of the greatest value in the development of the Gilpin County gold veins.

The mouth of the "great bore" has been located about two miles below Black Hawk, on the north branch of Clear Creek, some 7,000 ft. above the sea, 1,800 ft. above the plains, and nearly 1,200 below the level of Central City. Its course is a few degrees north of west, or in a direction that would intersect the Gregory, Fisk, Hunter and other lodes, 15 deg. to 20 deg. from a perpendicular. The Bobtail, Mammoth, Winnebago, and other lodes of that system would be cut at a very acute angle.

From the mouth of the tunnel to the Bobtail lode, in a direct line, is 11,000 ft., and from that point on to the Gregory, about 800 more. The course being about 30 deg. north of west, it will run under Central City, almost directly beneath Eureka street, and passing a short distance up that gulch, cut into Gunnell Hill, and pass through it into the main range.

The Bobtail is the first known lode of any prominence that will be intersected. This, as has been said, is 11,000 ft. from the mouth, and will be struck about 1,300 ft. from the surface. From this point on, the great bore will strike the Gregory, Bates or Hunter, Gunnell, Prize and Winnebago, in the order named. The three latter lodes are about 16,000 ft. from the mouth, and will be opened nearly 2,000 ft. from their surface outcroppings. Beyond these, if the tunnel ever reaches so far, it is not improbable that other valuable and large veins will be met with. The main divide between Central City and Middle Park is from 11,000 to 12,000 ft. high, in places rising to nearly 14,000 ft. In passing through this, the tunnel will reach its greatest depth, viz., from 5,000 to 7,000 ft.—*Mining Review*.

ORDNANCE AND NAVAL.

THE 400 LBS. SHELL OF THE HERCULES.—There may now be seen at the South Kensington Museum, a full size model of a 10 in. 400 lbs. common shell, similar to the one which recently disabled the 18-ton gun of the Hercules, but strengthened with five iron ribs instead of being weakened with fourteen stud holes, each $\frac{3}{10}$ in. deep and 1½ in. wide. To obviate "the oblique movement of the axis," which checks the exit of the shell, dislodges the fuse composition and causes premature explosions, the model of the Hercules 400 lbs. shell has had substituted a total rotating bearing of 115 in. on strengthening ribs for the 6 in. on weakening studs now relied upon. The grooves in the gun, to receive these five iron ribs, would only be about one half the depth, and one half the width of those in the Hercules 18-ton guns, and would necessitate the removal of only 14½ lbs. of metal from the bore, instead of 61½ lbs. as at present. This system of long centring ribbed bearings gave higher velocities and better endurance than the present service short stud bearings when tried against them in the heavy gun competition of 1865. On that occasion the so-called Woodwich rifling, with increasing spiral, destroyed its 7-in. 7½-ton gun in 567 rounds, whilst the ribbed rifling left the lands and groves unimpaired after 417 rounds. Moreover the 100 lbs. ribbed shot, though precisely similar in all respects, except the rifling, to the Woolwich one, struck a muzzle blow 133 foot tons heavier than the latter; and was thrown at 2 deg. of elevation to 1,473 yards with 5 lbs. less powder charge than the Woolwich one took to reach the same distance. Thus without any change, except in the rifling, a stronger shell is provided, with the effort of rotation diffused over nearly twenty times the surface; and a stronger gun is obtained with less strain upon it. The striking force, the powder capacity, and the endurance of the projectiles of the Hercules would thus be greatly increased; whilst the Royal Arsenal authorities have certified that the strong ribbed shell would cost £77 per thousand less than the weak studded ones, and the rifling of the gun be done at one-fifth less cost. As our heavy guns are occasionally injured by their own projectiles, even when firing deliberately at a target, a reconsideration of the mechanical principles involved may not be ill-timed or unnecessary.—*Engineering.*

A NEW FRENCH CRUISER.—A new vessel has just been commenced in the yard of the Seigne Var, on plans approved by the Council of the Admiralty, and ordered to be constructed by the Minister of Marine. The vessel is to be called the Tourville; it is to be 100 metres long and 15 metres wide. Its engines are calculated to develop a power of 7,000 horses, and to produce an average speed of 18 knots an hour. The hull is constructed of iron and teak of unusual solidity, and divided into water-tight compartments, described as being so happily planned as to render submersion impossible.

ANOTHER 18-TON GUN DISABLED.—By the premature bursting of a 400 lbs. common shell in the chase of an 18-ton gun at Shoeburyness, on the 18th inst., the inner steel tube was cracked in three places at the muzzle. The gun had to be dismounted and returned to the Royal Arsenal for repair. The fuse composition is supposed to have been dislodged by the action of the front studs in coming into bearing 12 in. from the muzzle. As this accident does not occur in the 25-ton guns, which have a sharper spiral, the supposition is that the reduction of the latter shell, one calibre in length, has contributed to their more perfect rotation, and to the safety of those guns, but at the cost of great loss of shell power, the common shell of the 18-ton gun being more formidable than that of the 11-in. 25-ton or the 35-ton gun.

BOOK NOTICES.

A TREATISE ON STEAM BOILERS, THEIR STRENGTH, CONSTRUCTION, AND ECONOMICAL WORKING. By ROBERT WILSON. London: Lockwood & Co. 1873. For sale by Van Nostrand.

The author of this little manual was at one time inspector to the Manchester Steam Users Association; and as such his experience was acquired in no limited field. He has brought with him to his task other qualifications quite as essential as experience—namely, common sense, and the power of expressing his opinions and imparting to others in simple, grammatical, well-chosen language, the information which he himself possesses. The work is, in its way, the best treatise that has ever been published on steam boilers. The author has very prudently confined his attention to certain principles of construction, and he has added to his exposition of these principles statements of fact gathered from his own experience, and instructions as to the best mode of carrying out certain details. In his preface the author says: "This book does not pretend to give any new facts or opinions upon the subjects of which it treats. Any claim to attention it may exert is based upon its being an attempt to embody the principles of boiler construction and management, together with numerous opinions collected from the writer's experience in boiler inspecting, and from various sources not accessible to the majority of those engaged or otherwise interested in the application of steam. Many of the opinions advanced, which are founded on experience, may require repeated modification with increased opportunities of observation, and as new light is brought to bear on the various questions by further experiments." These words show pretty clearly what is the scope and purport of the book.—*The Engineer.*

INTRODUCTORY TEXT-BOOK OF GEOLOGY. By DAVID PAGE, LL. D., etc. New Edition, enlarged. (London and Edinburgh: W. Blackwood & Sons. 1873.) For sale by Van Nostrand.

"The study of the structure of the earth," said Dr. James Hutton, nearly a century ago, "must tend to enlarge the mind of man, in seeing what is past, and foreseeing what must come to pass in the economy of nature; and here is a subject in which we find an extensive field for investigation, and for pleasant satisfaction." In this charming science, combined with a sufficient knowledge of chemistry, is the true groundwork of a mining engineer's practical education; and in an educa-

tional point of view there is no branch of human culture so truly catholic (in the old and true sense of that unhappy word) as geology. Nor is he a true geologist, who has not mastered many fields in the physical and natural sciences. The distinguished Professor of Geology in the Science College, at Newcastle, has for many years been the foremost compiler of text-books in this favorite field. This little volume is well known, and we mean merely to announce its existence; the more so that it is accompanied by a notice which we commend to authors of popular school-books. Dr. Page tells us that the continued demand for this little manual enables him at frequent intervals to make such alterations and additions as the progress of the science requires; and that while this revision has been enlarged so as to embody the latest views and discoveries—so far as these are compatible with the nature of an elementary outline—the original textual arrangement has been carefully preserved, that as little inconvenience as possible may be felt in using it in the same class along with any of the later editions. Apart from its scientific value, the study of geology affords, as Hutton has suggested, a source of pure pleasure; so that, to any man whether educated or not, who has a scientific bent, we can commend nothing more delightful than that careful study of geology to which Dr. Page, of all men, is the safest and best guide.

THE PRACTICAL DESIGNING OF RETAINING WALLS. By ARTHUR JACOB, A. B. New York: D. Van Nostrand.

This is No. 3 of Van Nostrand's Science Series, and is an excellent example of a handy book for the practical engineer. Works which present the rationale of the processes of mathematical investigations, and present in plain terms the application of the principles, are by no means too common; and this one subject of "Retaining Walls" is so overloaded with abstruse mathematical labor in most works on Engineering, that the exact conclusions of the author are hard to determine.

We have here, however, just so much of the theory as to indicate the nature and amount of the forces to be met, and the accepted method of meeting the conditions under all ordinary circumstances.

Appended to the Essay are some tables, also two excellent methods of solving by graphical construction problems relating to retaining walls.

SUBMARINE MINES. NOTES ON TORPEDOES, OFFENSIVE AND DEFENSIVE. By MAJOR R. H. STOTHERD, R. E. Washington: Government Printing Office.

This work has been compiled from the various papers which have been drawn up, and experiments which have been made, during the last few years in the course of instruction at the School of Military Engineering at Chatham.

The object has been to prepare a hand-book of reference for military engineers.

The several chapters present the selected topics in the following order: I.—Introductory. II.—General Principles. III.—Explosives. IV.—Form and construction of case. V. Mooring. VI.—Mode of Ignition. VII.—Electric cables. VIII.—Water-tight and insulated joints. IX.—Submerging mines. X.—Electrical igniting agents. XI.—Closing circuit. XII.—Electrical testing tables. XIII.—Mechanical and electrical tests. XIV.—Clearing channels of submarine mines. XV.—Locomotive torpedoes. XVI.—Approved forms of apparatus.

The illustrations are numerous and good.

THE ACHROMATIC MICROSCOPE. By RICHARD BECK. London: John Van Voorst. For sale by Van Nostrand.

A complete manual of Microscopy, designed especially to accompany the excellent apparatus of the well-known London manufacturers. The work is chiefly devoted to a description of the various parts of the microscope and its adjuncts, and to preparation of the ordinary kinds of objects. It is in no sense a theoretic treatise. The illustrations throughout are excellent and abundant.

MANUAL OF THE RAILROADS OF THE UNITED STATES, 1873–74. By HENRY V. POOR. New York: H. V. & H. W. Poor. For sale by Van Nostrand.

The design and scope of this Annual is now well known to all of our readers who have occasion to make use of railroad statistics.

We notice an improvement in the general appearance of the present over former editions.

The increase in size was of course to be expected. The work contains statistical imformation, carefully arranged, of the entire list of railroads of this country. In addition to such topics as earnings, expenditures, value of stock etc., it sets forth also, in many cases, the gauge, grades, location of termini, and present condition of the track.

The reliability of the work is sufficiently attested by the success of the former editions.

TRAITE ELEMENTAIRE DE CHIMIE EXPERIMENTAL ET APPLIQUEE. Par J. JACOB. Paris. For sale by Van Nostrand.

This treatise is particularly noticeable on account of the space devoted to processes of manufacture in the department of organic chemistry. In the first or inorganic portion it is much like our complete English treatises. The nomenclature is the old system.

A MANUAL OF ELEMENTARY CHEMISTRY.—Theoretical and Practical. By GEORGE FOWNES, F. R. S.—Eleventh edition (1873, revised and corrected by HENRY WATTS, F.R.S. London: J. & A Churchill. For sale by Van Nostrand.

We believe no work in the English language presents such an epitome of chemistry as Fownes'. It has for a long time held its place as the adopted text-book in many of our leading colleges, and especially the medical schools. The nomenclature of this edition is the new system.

VOIE, MATERIEL ROULANT, ET EXPLOITATION TECHNIQUE DES CHEMINS DE FER. Tome II. 2d Fascicule; Traction. Par M. CH. COUCHE. Paris: Dunod. For sale by Van Nostrand.

The part before us of this extensive work is devoted to "Materiel de Transport," and "Traction," and these topics alone occupy about nine hundred octavo pages. All the illustrations are given in the large folio atlas of ninety-two plates. This last is a remarkable collection of plates of

cars and locomotives (chiefly the latter) for all ordinary or extraordinary traffic in all parts of the globe. The details are given in many examples with the minuteness and accuracy of working drawings.

LEITFADEN ZUR BERGBAUKUNDE. Von HEINRICH LOTTNER. Bearbeitet von Dr. ALBERT SERLO. Berlin, 1873; Julius Springer. For sale by Van Nostrand.

This complete work on mining is presented in two octavo volumes containing 540 wood-cuts and 14 lithographic plates.

The descriptions of machinery and processes, together with the history of the various improvements, is given with a fulness that is only afforded by our indefatigable German friends, when writing up a department of technical science.

CATALOGUE OF SCIENTIFIC INSTRUMENTS.—Illustrated and Descriptive. By L. CASELLA. London. For sale by Van Nostrand.

Much information on the subject of the refinements of manipulation in scientific research, is conveyed by a well-illustrated catalogue of scientific instruments.

Mr. Casella is well known to scientific investigators through his excellent devices for the exact measurement of temperature, pressure, and velocity of air or water under extraordinary conditions. The catalogue, however, describes the whole range of scientific apparatus.

IMPROVEMENT IN METALS FOR CAR WHEELS. Published by the Hamilton Steeled Wheel Co., Philadelphia.

This, although only an advertisement, contains much valuable information aside from the numerous photolithographs of fractured surfaces of cast iron.

THE MOON, HER MOTIONS, ASPECT, SCENERY, AND PHYSICAL CONDITION. By RICHD. A. PROCTOR, B. A. New York: D. Appleton & Co. For sale by Van Nostrand.

All scientific readers know the value of Mr Proctor's writings so well that any remarks upon the scientific value of this last treatise would be useless.

The volume is of uniform size with "The Sun," and all of his later works. It presents to the cursory glance even a more attractive appearance than the former works, by reason of the great abundance of illustrations.

These photographs of the lunar surface by Rutherford, embellish the work; and two charts exhibiting the named mountains and waters.

To a student of astronomy, or to the reader of general science who desires to keep pace with its progress, the book is indispensable.

A GENERAL SYSTEM OF BOTANY, DESCRIPTIVE AND ANALYTICAL. By EMM. MAOUT and J. DECAISNE. Translated by Mrs. HOOKER. London: Longmans, Green & Co.

The size of this elegant volume is so far beyond what we are accustomed to see in botanical textbooks, that absolute completeness in treatment of this department of natural history is naturally suggested at the first glance at it.

The two parts which constitute the volume together cover more than one thousand quarto pages.

Part First treats of Organography, Anatomy, and Physiology of Plants.

Part Second is devoted to "Descriptions and Illustrations of the Orders." The great feature of the work is the completeness of the pictorial illustration of the entire anatomy of each of the orders.

The arrangement is that adopted by the universities and schools of Great Britain and the United States. An Appendix sets forth the natural method and a synopsis of the orders; this latter is by J. D. Hooker, C. B., Director of the Royal Botanical Gardens at Kew.

The typography is excellent; the cuts are interspersed through the text, and the whole is on tinted paper.

THE STEREOSCOPE. By Prof. CHAS. F. HINES, Ph. D. For sale by Van Nostrand.

This interesting treatise is republished in pamphlet form from the "Journal of the Franklin Institute." It is quite exhaustive on the subject of binocular vision, and possesses a special interest for students of physical science.

FORMULAS AND TABLES FOR ARCHITECTS AND ENGINEERS. By F. SCHUMANN, C. E. Washington: Warren, Choate & Co. For Sale by Van Nostrand.

The object of this convenient table book as explained by the author, is to give a compilation and transformation into simple formulas and tables, adapted to practice, of matter contained in the works of Weisbach, Rankine, Fairbairn, and others.

As a special feature may be mentioned the tables for the capacity of rolled and cast iron beams of various cross sections.

The usual mathematical tables are also given.

FLAMMARION'S ATMOSPHERE.—THE ATMOSPHERE. Translated from the French of CAMILLE FLAMMARION, edited by JAMES GLAISHER, F. R. S., etc. (London: Sampson, Low and Co., 1873.) For sale by Van Nostrand.

In some respects the volume before us may be considered as the sequel to its equally sumptuous companion, "The Forces of Nature." For, the ordinary reader must have some acquaintance with physics intelligently to follow the disentanglement of the various forms of energy—the mingled play of which gives rise to the phenomena of meteorology. Nevertheless, M. Flammarion writes so lucidly and pleasantly, that a totally unscientific person can read this work with enjoyment and instruction. On the other hand, it contains much that will be of interest to the man of science, as well as to the mere dilettante.

The scope of the work is stated in the editor's preface. It treats of the form, dimensions, and movements of the earth, and of the influence exerted on meteorology by the physical conformation of our globe; of the figure, height, color, weight, and chemical components of the atmosphere; of the meteorological phenomena induced by the action of light, and the optical appearances which objects present as seen through different atmospheric strata; of the phenomena connected with heat, wind, clouds, rain, electricity; and also of the laws of climate. These subjects are illustrated by ten admirable chromo-lithographs, and upwards of eighty woodcuts, but many of these latter we observe have already done duty in other French treatises. The colored illustrations are

quite works of art; especially noteworthy are the representations of a sunset, of sunrise as seen from the Righi, and of a solar and a lunar rainbow. Science has more often given than received aid from art, but the pages of this book show how much service art can render to science. The printing is remarkably well executed.

The translation has been done by Mr. E. B. Pitman, and the task has been well discharged. The value of the original work is considerably increased by the careful revision it has received from Mr. Glaisher, and the additions by him of many useful foot-notes. The tendency of M. Flammarion, like other popular French writers, to run into grandiloquent language has been in general suppressed; though still a few cases remain that might well have been pruned.

As indicative of the labor Mr. Glaisher has bestowed on this work, we notice that all measurements are given in English equivalents, centigrade degrees are converted to Fahrenheit, Paris observations are replaced by data from Greenwich, and appropriate condensation and excision has reduced by one-half the unwieldy size of the original work. —*Nature.*

A Manual of Practical Military Engineering. By Capt O. H. Ernst, Corps of Engineers. New York: D. Van Nostrand.

This is an entirely new text-book, prepared for the use of the Cadets of U. S. Military Academy at West Point, and for Engineer troops. It is already adopted at the Military Institute of Virginia.

The author acknowledges many sources from which the work has been compiled, and modestly compares his production to a mathematical work in which the materials have been gathered from previous compilations, and the original authors are long since forgotten.

The standard works are, however, mentioned as prominent sources of supply for the author.

There is nothing in the work to indicate a patchwork; on the other hand, there are plain indications throughout of the logical method of a thorough instructor. The result is such a book as the learner is first attracted to and profited by. The illustrations are very numerous, and the typography excellent. We shall review the work more in detail at a future time.

A Treatise on Electricity and Magnetism. By James Clark Maxwell, M. A. Oxford: Clarendon Press. For sale by Van Nostrand.

This elegant work, in two octavo volumes, presents us with the *theory* of electricity and magnetism elucidated by aid of the higher analysis. The subjects treated in order by chapters are: The Measurement of Quantities—Description of Phenomena—Elementary Mathematical Theory of Electricity — Systems of Conductors — General Theorems—Mechanical Action between Electrified Bodies—Points and Lines of Equilibrium—Points of Equipotential Surfaces and Lines of Flow—Simple Cases of Electrification—Spherical Harmonics—Confocal Surfaces of the Second Degree—Theory of Electrical Images—Conjugate Functions in Two Dimensions—Electrostatic Instruments—Electric Current—Conduction and Resistance—Electro-motive Force—Electrolysis — Electrolytic Polarization—Theory of Distribution of Currents—Conduction in Three Dimensions—Resistance and Conductivity in Three Dimensions—Conduction through Heterogeneous Media—Conduction in Dielectrics—Measurement of Resistance—Resistance of Substances.

Vol. II. Elementary Theory of Magnetism—Magnectic Force and Magnetic Induction—Particular Forms of Magnets—Induced Magnetization—Magnetic Problems—Weber's Theory of Magnetic Induction—Magnetic Measurements—Terrestrial Magnetism — Electro-magnetic Force — Mutual Action of Currents—Induction of Electric Currents—Induction of a Current on Itself—Dynamics applied to Electro-magnetism—Electrokinetics—Exploration of the Field with Secondary Circuit—General Equations—Dimensions of Units—Energy and Stress—Current Sheets—Parallel Currents—Circular Currents — Electro-magnetic Instruments—Measurement of Coefficients of Induction—Determination of Resistance—Comparison of Units—Electro-magnetic Theory of Light—Magnetic Action on Light—Electric Theory of Magnetism—Theories of Action at a Distance.

The object of the author throughout is to combat the notion of action at a distance.

MISCELLANEOUS.

Great Russian Railway.—The capital of the Great Russian Railway Company is guaranteed an interest of 5 per cent. per annum by the Russian Treasury, but the guarantee does not appear to give any trouble to the Russian Minister of Finance, since the Company's profits not only wholly cover it, but also left last year a balance sufficient to pay a small supplementary dividend, viz., 66 copecks, or 1s. 10d. per share. The lines of the Great Russian extend from St. Petersburg to Warsaw, from St. Petersburg to Moscow, and from Moscow to Nijni-Novgorod.

Foreign papers report that considerable use is now made of gas as a means of lighting mines. A patent apparatus has been fixed at many collieries in South and West Yorkshire, as well as in the North of England coal-fields. Some excellent teetimonials have been received as to the efficient way in which it is performing its work. The jet can be applied to almost any depth, it being now in use 500 yards below the surface of the ground. A steam jet is used to draw gas into and force it down a pipe to the bottom of the mine.—*Engineering and Mining Journal.*

A Howard boiler without a seam or rivet has lately been built in Edinburgh. It is constructed of lap-welded iron tubes of large diameter, and fixed in such a way that every part of the boiler internally is made easy of access for cleaning or repairs. From its construction it is believed that it insures almost entire immunity from dangerous explosions, and its strength is so great that it is able to carry a very much higher pressure than is customary in land boilers.—*Engineering and Mining Journal.*